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PROGRAM MANAGER

Modeling and Simulation Feature Issue

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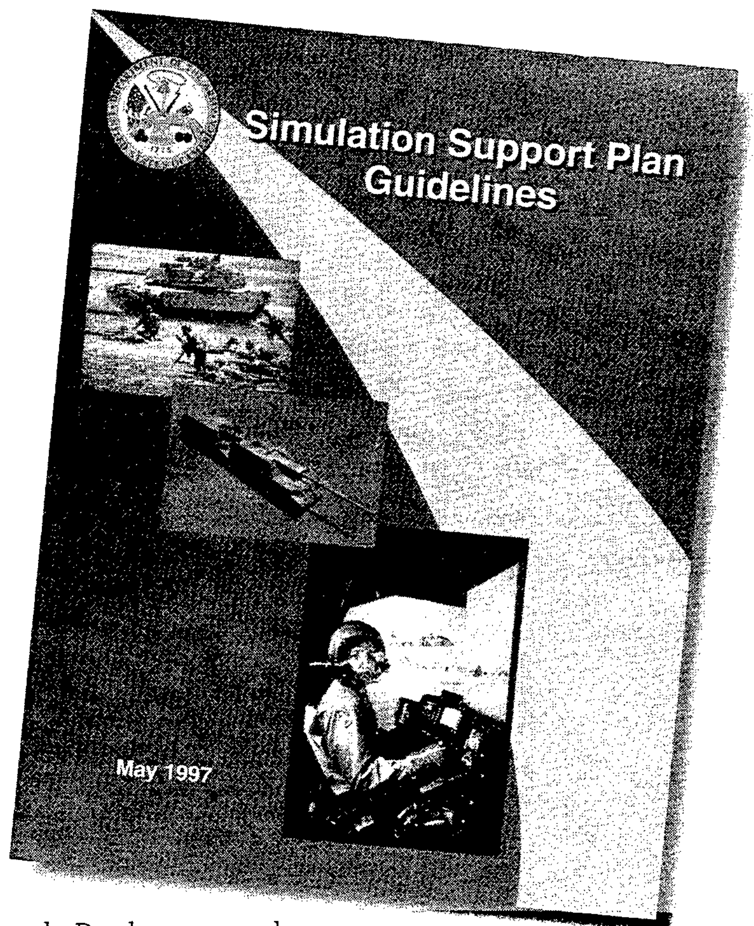
DTIC QUALITY INSPECTED 1

Longuemare Endorses Two Important Modeling and Simulation Documents

RANDY ZITTEL



In 1993, the Army established a policy requiring that all major program managers (PM) plan their use of modeling and simulation (M&S) throughout their programs. Because early planning in a program or project is crucial, and M&S is expensive, the Army weighed carefully its decision to require that all PMs document their planning efforts in a specific Simulation Support Plan (SSP). The positive potential of M&S for accelerating schedules, reducing cost, and improving quality was a key acquisition reform initiative that Army senior acquisition managers wanted to exploit. Because of the SSP's effectiveness, in 1996 the Army expanded its SSP requirement to include ACAT III and IV Army program and product managers. The intent was to provide program and product managers a management tool that would result in increased M&S focus and coordination.

The Army recently published an excellent pamphlet to assist PMs in better understanding the importance and value of the SSP. The Assistant Secretary of the Army for Research, Development, and Acquisition just released *Simulation Support Plan Guidelines*, May 1997, to all acquisition managers.

In a memorandum to all other Service Acquisition Executives, May 2, 1997, R. Noel Longuemare, Principal Deputy Under Secretary of Defense for Acquisition and Technology, provided copies of the SSP Guidelines, and recommended their use in all Department of Defense (DoD) programs.

The *Simulation and Support Plan Guidelines* will soon be available on the Assistant Secretary of the Army for Research, Development, and Acquisition (ASARDA) Home Page:

http://www.sarda.army.mil

To obtain a copy of the *Guidelines*, send an E-mail to: **purdye@sarda.army.mil** or call (703) 614-5920.

Another important document relating to current use of DoD M&S came out of the Office of the Secretary of Defense (OSD). Its "Study on the Effectiveness of Modeling and Simulation in the Weapon System Acquisition Process" is an excellent overview of current DoD use of M&S and its potential for the future. The all-encompassing concept of SBA is introduced here, and the study provides a tremendous wealth of M&S use in current programs. Longuemare distributed the study report to all major DoD PMs in his memorandum of March 28, 1997, as an indication of M&S value, and challenged each PM to use M&S to the maximum extent possible, "to continuously reduce life cycle costs." This capstone study is available through the Defense Modeling and Simulation Home Page (**http://www.dmso.mil**) on the World Wide Web.

Editor's Note: Zittel is a Professor of Systems Engineering, Faculty Division, DSMC.

THE UNDER SECRETARY OF DEFENSE
3010 DEFENSE PENTAGON
WASHINGTON, DC 20301-3010

ACQUISITION AND TECHNOLOGY

MAY 2 1997

MEMORANDUM FOR COMPONENT ACQUISITION EXECUTIVES

SUBJECT: Simulation Support Plans

As part of our reform efforts, I have continued to encourage an increasing emphasis on the use of modeling and simulation (M&S) in our acquisition programs to reduce cost and schedule without sacrificing quality or performance. A key initiative in this area is the concept of Simulation Based Acquisition (SBA), the employment of models and simulations across all functional areas throughout the entire acquisition life cycle.

To foster the use of M&S in acquisition, and as part of their move towards SBA, the Army recently published the attached "Simulation Support Plan (SSP) Guidelines." The SSP, in widespread use within the Army, is a means for developing and implementing an effective strategy for the use of M&S throughout a program's life cycle, and facilitates a Program Manager's (PM's) thinking through and resourcing a M&S program. The SSP *Guidelines* provide guidance to PMs on developing such a plan, and highlight the issues the PM should address in identifying how M&S can support system development throughout the entire acquisition life cycle.

These guidelines not only provide a useful tool for the PM's M&S tool kit, but are also a good example of how the acquisition community can begin to implement the concept of SBA. I therefore encourage you to make these Army guidelines known and available to your communities as one more step towards developing and fielding our systems as efficiently as we possibly can.

R. Noel Longuemare
Principal Deputy

Attachment

PRINCIPAL DEPUTY UNDER SECRETARY OF DEFENSE

3015 DEFENSE PENTAGON
WASHINGTON DC 20301-3015

ACQUISITION AND TECHNOLOGY

MAR 28 1997

MEMORANDUM FOR PROGRAM EXECUTIVE OFFICERS
ACAT I PROGRAM MANAGERS
ACAT II PROGRAM MANAGERS

SUBJECT: Study on the Effectiveness of Modeling and Simulation in the Weapon System Acquisition Process

As you continue to manage weapon system acquisition programs to the highest standards, you have many resources available to assist you in building affordable, executable strategies. I urge you to count this study as one of the many sources of information you use as you plan and execute your programs.

This study will aid you in getting a perspective on the modeling and simulation (M&S) tools and technologies available that can positively impact your program management. Many of the examples in this study reinforce what I continue to emphasize: emerging technologies, integrated with systems engineering, can result in cost avoidance through process efficiencies in your program's life cycle. They can also reduce your program's acquisition cycle time.

Performance, cost, and schedule are central to the execution of your programs, and you can influence each of these by leveraging some of the M&S tools and technologies available in the commercial and defense communities today. I challenge each of you to continue to insert emerging technology at an affordable cost and to use available processes to continuously reduce life cycle costs. You can make a difference in changing the way we execute programs.

R. NOEL LONGUEMARE

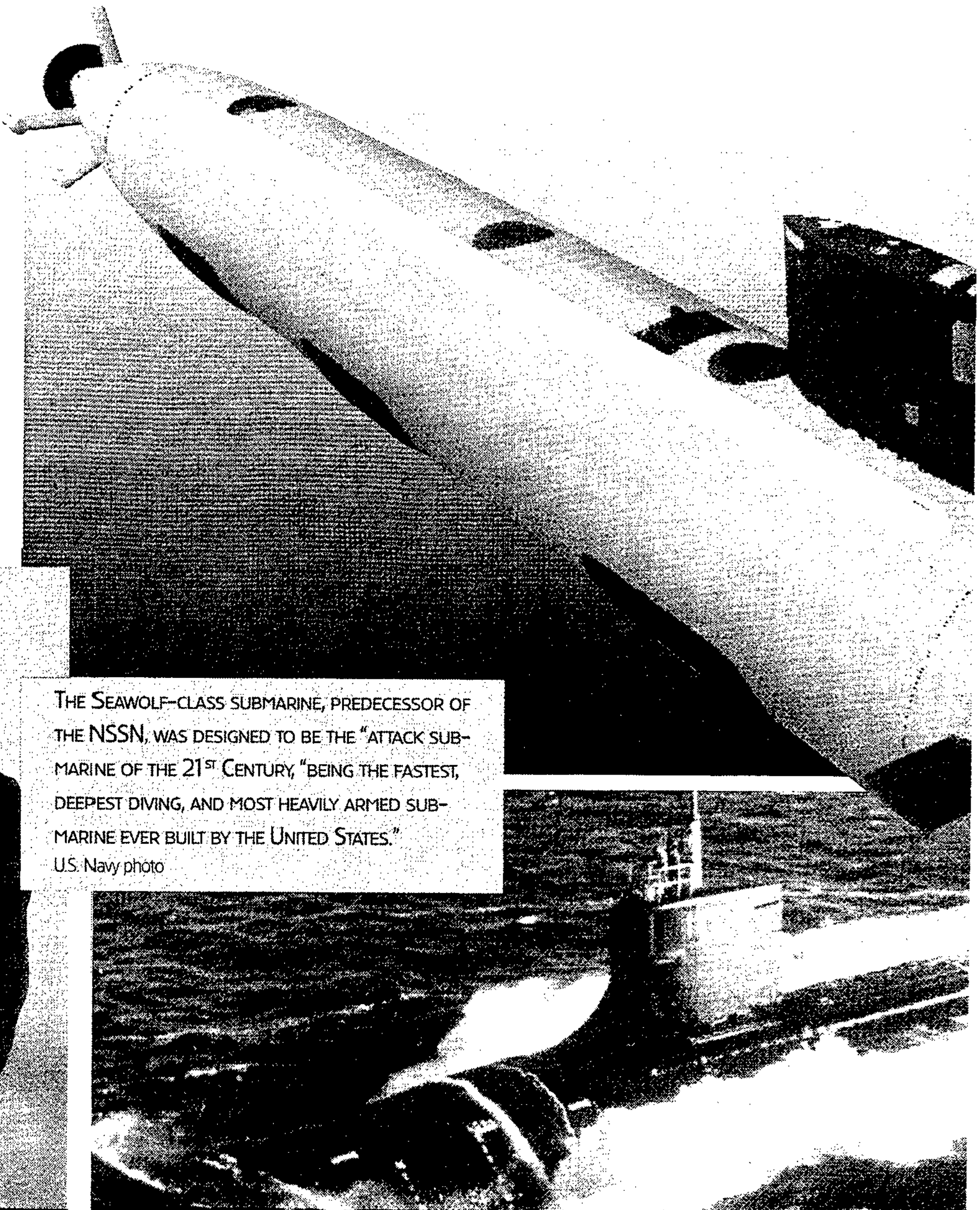
Attachment:
As stated

Simulation Based Acquisition

An Effective, Affordable Mechanism for Fielding Complex Technologies

DR. PATRICIA SANDERS

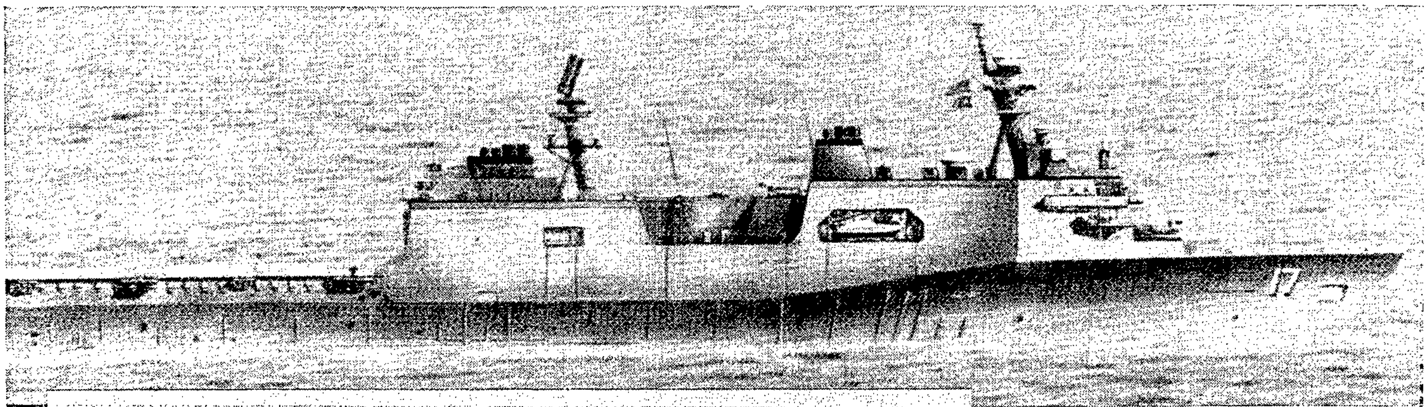
Defense modernization has come a long way technologically, and the United States may have reached a point where it is paying a penalty for past successes. During the Cold War, some argued that the country should not purchase the equipment the nation's industries were producing because it was unlikely to work. Today, not long after the Persian Gulf experience, these same people allege the government should not purchase the equipment that is being produced because it works so well no more is needed.



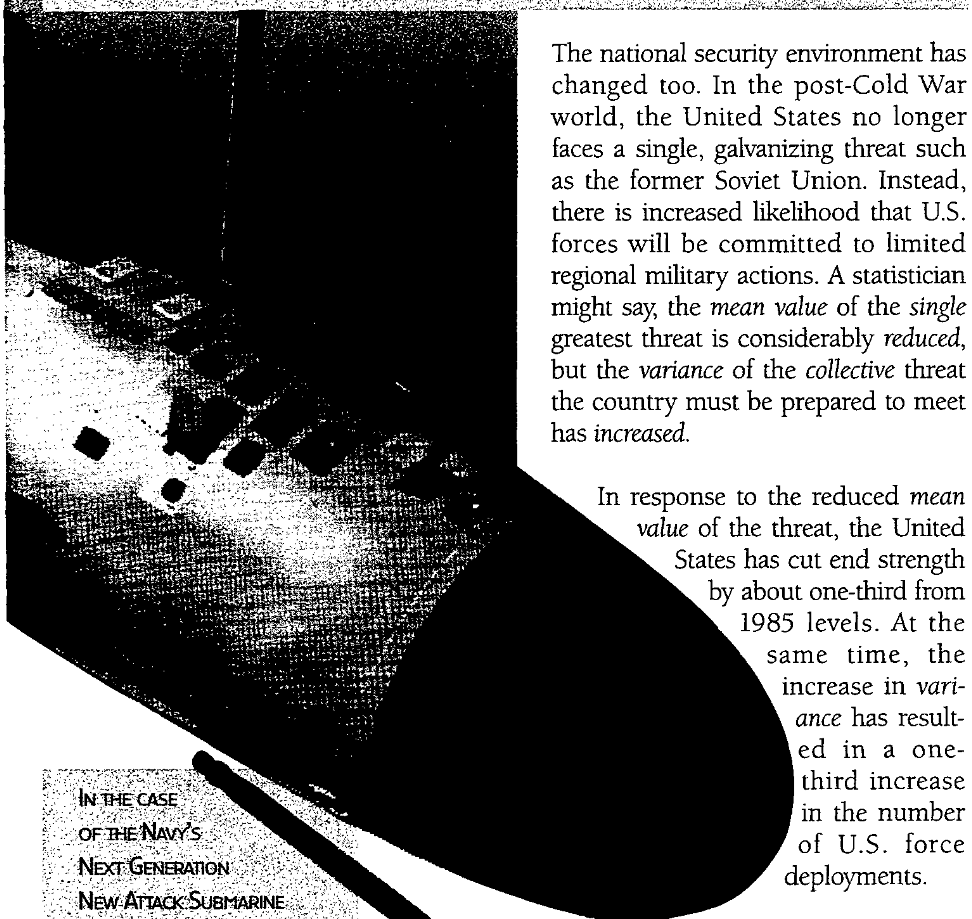
THE SEAWOLF-CLASS SUBMARINE, PREDECESSOR OF THE NSSN, WAS DESIGNED TO BE THE "ATTACK SUBMARINE OF THE 21ST CENTURY, "BEING THE FASTEST, DEEPEST DIVING, AND MOST HEAVILY ARMED SUBMARINE EVER BUILT BY THE UNITED STATES."
U.S. Navy photo

NORM AUGUSTINE, CHIEF EXECUTIVE OFFICER OF LOCKHEED MARTIN, POINTED OUT SOME YEARS AGO THAT THE COST OF EACH SUCCESSIVE GENERATION OF FIGHTER AIRCRAFT WAS INCREASING GEOMETRICALLY...SOME TIME IN THE MIDDLE OF THE NEXT CENTURY, THE COUNTRY WOULD BE ABLE TO AFFORD ONLY ONE FEARSOME, SOPHISTICATED AIRCRAFT!
Photo by Bachrach

Sanders is the Director, Test, System Engineering and Evaluation, Office of the Under Secretary of Defense (Acquisition and Technology).



THE NAVY'S NEWEST CLASS OF SHIP, THE LPD 17, IS SCHEDULED TO REPLACE THE MAJORITY OF THE NAVY'S AMPHIBIOUS FLEET. THE LPD-17 PROGRAM SAVED $6 MILLION IN DESIGN COSTS THROUGH THE USE OF NEW MODELING AND SIMULATION TOOLS. AT THE SAME TIME, IT WAS ABLE TO ELIMINATE 100 TONS IN TOPSIDE WEIGHT, A DESIGN CHANGE EXPECTED TO RESULT IN GREATLY IMPROVED PERFORMANCE. THE NAVY ANNOUNCED THE CONTRACT AWARD FOR LPD-17 ON DEC. 17, 1996, TO GENERAL DYNAMICS LAND SYSTEMS, WHICH WILL BUILD THE LPD-17 FOR THE MARINE CORPS.
Photo courtesy General Dynamics Corporation



IN THE CASE OF THE NAVY'S NEXT GENERATION NEW ATTACK SUBMARINE (NSSN), NEW MODELING AND SIMULATION TOOLS HELPED REDUCE THE STANDARDS PARTS LIST TO ABOUT 16,000 ITEMS FROM THE 95,000 ITEMS LISTED FOR THE EARLIER SEAWOLF-CLASS SUBMARINE.
U.S. Navy Digital Representation

The national security environment has changed too. In the post-Cold War world, the United States no longer faces a single, galvanizing threat such as the former Soviet Union. Instead, there is increased likelihood that U.S. forces will be committed to limited regional military actions. A statistician might say, the *mean value* of the *single* greatest threat is considerably *reduced*, but the *variance* of the *collective* threat the country must be prepared to meet has *increased*.

In response to the reduced *mean value* of the threat, the United States has cut end strength by about one-third from 1985 levels. At the same time, the increase in *variance* has resulted in a one-third increase in the number of U.S. force deployments.

Procurement Reductions

The overall U.S. Department of Defense (DoD) budget has been cut by about one-third in real dollars since its peak in the late 1980s. When one considers that the procurement budget changes by two percentage points for every percentage point the overall DoD budget changes (up or down), one realizes that a significant decrease (about two-thirds) in procurement funding has taken place.

Traditionally, procurement has been the most volatile component of a DoD budget drawdown because –

- the acquisition of new equipment for a smaller force structure is viewed as unnecessary; and
- there is an emphasis on near-term readiness and a willingness to gamble on what constitutes acceptable technology.

The effect of such procurement reductions on the ultimate user of the equipment, i.e., the soldier, sailor, airman, or marine, must not be underestimated. If the issue of equipping the military forces is seen as a business proposition, one can readily calculate – by dividing the value of all tangible assets the DoD owns (exclusive of land and buildings) by the annual reinvestment in those same assets – that the average item of military equipment in America's inventory will have to last 54 years! This in a world where technology generally has a half-life of from two to 10 years, and combat casualties are directly related to the quality of technology employed.

Since this approach to the budget defers long-term modernization and is certain to have an adverse effect on future readiness, it must be interpreted as a temporary condition.

Need for Modernization Strategy

In view of the overall federal budget, it is only realistic to assume there will be continued pressure to limit increases in defense investment spending. In such a climate, it is important to think in terms of a *modernization*, rather than *recapitalization*, strategy for equipping U.S. forces. *Recapitalization* suggests a one-for-one replacement of existing platforms with new platforms having similar capabilities. *Modernization* means developing and fielding fewer, more capable systems. The key question is: Can the Defense Department afford a modernization-based investment approach? Technological complexity is certain to increase, dramatically in many instances.

Norm Augustine, Chief Executive Officer of Lockheed Martin, pointed out some years ago that the cost of each successive generation of fighter aircraft was increasing geometrically. As a result, although fighter aircraft were becoming more and more deadly, the United States could afford fewer and fewer of them. Augustine's calculation – an empirical plot of aircraft unit cost as a function of deployment date – was that by some time in the middle of the next century, the country would be able to afford only one fearsome, sophisticated aircraft!

The geometric increase in cost results because complex technologies become more and more interdependent. For example, a radio can interfere with aircraft flight controls or have an impact on electronic warfare equipment. To reduce radar signatures, designers may have to shape an aircraft in a way that forces them to move engines, weapons, and even the pilot. Any of these actions can affect other parts of a system's operation, not to mention its producibility or logistics support.

It is essential to remember that Augustine's prediction is empirical. It is based on past experience and processes for handling the interaction of increasingly complex technologies. Industry and the DoD need to share responsibility for finding an alternative path to fielding affordable, modern systems.

Becoming a "Smart Buyer"

The DoD needs to become a "smart buyer," in terms of both *what* and *how* it buys equipment. The *"what"* is at least as important as the *"how."*

What to Buy?

To determine what it will buy, the DoD is placing considerable emphasis on a "system-of-systems" decision-making approach, or construct. The goal is to select the most cost-effective mix of individual systems for development and fielding. Tradeoffs between on-board and off-board capabilities are being considered, and alternative systems are being evaluated under simulated combat conditions.

Recently, the Heavy Bomber Study looked at the adequacy of the planned bomber force in the context of a two-major-region, contingency scenario. The Strategic Airlift Force Mix Analysis and Tactical Utility Analysis were used to evaluate the cost effectiveness of various mixes of C-17 aircraft and nondevelopmental airlift platforms to perform airlift missions in support of various contingency operations. A similar study is currently in progress to evaluate the mix of accurately guided weapons the Department is procuring.

A hierarchy of models and simulations is being used to support these studies and to help make the what-to-buy decisions. First, at the engagement or system level, the system effectiveness against an adversary system is evaluated. Later, at the mission/battle or force-on-force level, the ability of a multiple platform force package to perform a specific mission is assessed. Finally, in theater- or campaign-level simulations, the conflict outcomes are determined for a total package of Joint and Combined forces.

Extensive use of constructive models for these system-of-systems evaluations is anticipated. Eventually, there will be much greater use of virtual prototypes operated on synthetic battlefields. Without question, the DoD is moving toward greater use of simulation-based system evaluations.

The Department's what-to-buy decisions are also being driven by life-cycle-cost-performance trades where cost is an independent variable. Gone are the days when performance was paramount, and cost took a back seat and was treated as a dependent variable. Life-cycle-cost-performance trades require evaluation of alternative designs and concepts. Computer modeling and simulation, including virtual prototypes, are needed to assess the performance of alternative designs in a simulated combat environment. They are also needed to examine the logistics, manufacturing, and producibility implications of alternative designs, and the cost and schedule impacts of pursuing alternative designs.

How to Buy?

The DoD must also change how it buys. The Department has worked to find the best methods for reengineering its processes. In May 1995 the Secretary of Defense directed a "fundamental change in the way we acquire goods and services" and mandated that the concepts of Integrated Product and Process Development (IPPD) and Integrated Product Teams (IPT) "be applied throughout the acquisition process to the maximum extent possible."

The DoD defines IPPD as "a management process that integrates all activities from product concept through production/field support, using a multifunctional team, to simultaneously optimize the product and its manufacturing and sustainment processes to meet cost and performance objectives." An outgrowth of concurrent engineering practices, the IPPD process reflects a systems engineering approach that has incorporated sound business practices and commonsense decision making. Fundamental to the successful implementation of the IPPD concept will be the willingness of organizations to undertake and experi-

ence profound changes in their cultures and past practices.

To reduce the costs associated with the integration of complex systems, it will be essential for the functional members of an IPT (e.g., design engineering, manufacturing, logistics, product support) to understand the concerns of their counterparts and to identify a program's technical challenges as early as possible. Tools available to an IPT include standard, relatively inexpensive computer equipment, virtual prototypes, and simulations. Such resources can aid in the development of a shared vision of the proposed system and provide a means for understanding the complex interactions among the configuration items in the system design.

The real power of a computer-based modeling and simulation system lies in the connection and coordination between the tools and the functional users. In addition to increasing the effectiveness of the design and manufacturing functional specialists, the product support members of the team (e.g., testers, logisticians, and maintainers) will benefit as well.

Simulation Based Acquisition

The DoD envisions an acquisition process supported by the robust, collaborative use of simulation technology that is integrated across acquisition phases and programs. The objectives of Simulation Based Acquisition (SBA) are to —

- reduce the time, resources, and risk associated with the acquisition process;
- increase the quality, military utility, and supportability of systems developed and fielded; and
- enable IPPD from requirements definition and initial concept development through testing, manufacturing, and fielding.

The real power of a computer-based modeling and simulation system lies in the connection and coordination between the tools and the functional users.

Substantial evidence has already accumulated regarding the value of a simulation-based approach to acquisition. Both commercial and military programs provide pervasive evidence of tangible results that can be measured in terms of improvements in *cost, schedule, productivity,* and *quality/performance.*

Cost

The LPD-17 program saved $6 million in design costs through the use of new modeling and simulation tools. At the same time, it was able to eliminate 100 tons in topside weight, a design change expected to result in greatly improved performance. In the Joint Strike Fighter program, it is projected that virtual manufacturing techniques may save as much as 3 percent of the program's estimated life-cycle cost, which could be $5 billion.

Schedule

The use of modeling and simulation tools and processes by the "big three" auto manufacturers has reduced the time from concept approval to production from five to three years, and significant further schedule reductions are anticipated. Separately, Electric Boat™ reports it has been able to halve the time required for submarine development, from 14 to seven years.

Productivity

Productivity is also affected by the increased use of modeling and simulation. The required level of effort (person years) is often less, and fewer workers may be needed. Costly intermediate steps (e.g., mockups, redesigns, and engineering changes) can frequently be avoided, there is reduced scrap, and less manufacturing floor space is required when modeling and simulation are used.

It took 38 Sikorsky draftsmen approximately six months to develop working drawings of the CH-53E Super Stallion's outside contours. In contrast, using modeling and simulation one engineer was able to accomplish the same task for the Commanche helicopter in just one month. In another instance, 14 engineers at the Tank and Automotive Research and Development Center designed a new, low-silhouette tank prototype in only 16 months, a task that would have required approximately 55 engineers and three years with more traditional methods.

Quality/Performance

The positive impact of modeling and simulation on quality and performance can be seen in a number of areas, e.g., the proper assembly of products and systems, fewer instances where rework is needed, a reduced parts count, and the opportunity for early design evaluation prior to further design efforts.

For example, Northrop's use of CAD [computer-aided design] systems led to a first-time, error-free, physical mockup of many sections of the B-2 aircraft. In the case of the Navy's Next Generation New Attack Submarine, new modeling and simulation tools helped reduce the standards parts list to about 16,000 items from the 95,000 items listed for the earlier Seawolf-class submarine.

Embracing This Approach — What is Needed?

It is clear that IPPD, backed by a strong commitment to computer-based modeling and simulation tools, provides a dominant and competitive edge in the commercial marketplace and a distinct warfighting advantage on the battlefield. It provides an alternate path for getting to market first, at lower cost. In the process, quality is improved. The underlying technology is widely available, and market forces are driving industry toward SBA. So what is needed to fully embrace this approach?

SBA is comprised of three principal components. The first is an *advanced systems engineering environment* that uses formal methods and automation to support efficient design synthesis, capture, and assessment, as well as other complex life-cycle activities. The SBA engineering environment provides a means for executing a process that can be extended, tailored, and repeated. The process results in the creation of reusable design repositories and products that can be reengineered. The potential gains from the use of such an advanced SBA environment will not be realized until the engineering process, as well as its people and organizations, also evolve.

The second component is a *refined system acquisition process* that takes advantage of the SBA systems engineering environment capabilities. The third component is a culture that has evolved to a point where *enterprise-wide cooperation* is the rule, and individual technical contributions and innovations are encouraged and managed efficiently.

SBA *is not an incremental step* beyond current system engineering methods and tools. Instead, it represents *a major paradigm shift* toward a comprehensive, integrated environment that addresses the entire system development life cycle and the spectrum of engineering and management domains.

It is clear that IPPD, backed by a strong commitment to computer-based modeling and simulation tools, provides a dominant and competitive edge in the commercial marketplace and a distinct warfighting advantage on the battlefield.

The benefits from the SBA process will be realized not only as time and cost savings within individual programs, but also as cost savings when a program makes use of design repositories and reengineered tools and products from other programs.

Cross-Program Use of Data, Tools, and Techniques

Modeling and simulation tools, as enablers for IPPD development, are already being applied successfully to reduce development time and life-cycle costs in a range of ongoing acquisition programs. The issue is no longer whether extensive use of modeling and simulation tools has merit, but rather how to develop and apply a new acquisition process in a deliberate and coordinated manner that uses these tools to maximum advantage and achieves even more dramatic reductions in cost, schedule, and risk.

The challenge for acquisition reform is to provide the catalyst that will expand the growing successful use of modeling and simulation tools beyond vertical applications within individual programs. If this is accomplished, even more significant benefits will be realized through the shared use of data, tools, and techniques by government and industry. Unambiguous communication is required to achieve full application of the IPPD and IPT processes; such communication can serve as the catalyst that encourages a new acquisition culture to use these powerful new tools and processes.

Partnership

The challenge is clear: The trend toward geometrically escalating costs in successive generations of defense equipment must be reversed. Limiting the sophistication, and therefore the capability, of future systems is not a realistic option. The task is to field increasingly complex technologies at a more affordable cost, in less time.

This will require a team effort by industry and the DoD to field a superior capability, affordably and in less time than potential adversaries. Industry needs to use the latest information technologies to upgrade its integrated product capabilities. The DoD needs to become a smarter buyer. Together, industry and government must ensure that the acquisition management culture evolves to —

- take advantage of IPPD approaches that stress the need for a shared vision and continuous insight to ensure that quality is built into programs from the start;
- emphasize prevention over cures by using virtual prototypes and simulations to identify and resolve problems early; and
- focus on overall program success, not functional area performance.

The appropriate vehicle for meeting this challenge is SBA, a method which combines a new process, new tools, and a new culture to develop a strong collaborative partnership between government and industry.

Dr. Patricia Sanders

Director Test, Systems Engineering and Evaluation (DTSE&E)

Dr. Patricia Sanders is the Director, Test, Systems Engineering and Evaluation (DTSE&E) for the Department of Defense (DoD) where she is responsible for ensuring the effective integration of all engineering disciplines into the system acquisition process. These include design, production, manufacturing and quality, acquisition logistics, modeling and simulation, and software engineering, with emphasis on test and evaluation as the feedback loop. She is also responsible for oversight of the Department of Defense's Major Range and Test Facility Base (MRTFB) and the development of test resources such as instrumentation, targets, and other threat simulators. The MRTFB comprises more than 50 percent of the DoD land resources, represents a capital investment of more than $25 billion, and employs approximately 47,000 government and contractor personnel. Sanders chairs the Defense Test and Training Steering Group, the Systems Engineering Steering Group, and the Acquisition Council on Modeling and Simulation. She reports directly to the Principal Deputy Under Secretary of Defense for Acquisition and Technology.

Sanders has over 22 years of experience in the Department of Defense with particular emphasis in the areas of test and evaluation, modeling and simulation, resource allocation, and strategic planning. Prior positions within the Office of the Secretary of Defense included serving as the Deputy Director for Test Facilities and Resources, the Director of Land Forces in the Office of the Assistant Secretary of Defense for Program Analysis and Evaluation, and as a Staff Specialist for the Director of Operational Test and Evaluation. Other assignments have included serving as Deputy Director for Analysis, United States Space Command; Science Advisor to the Command, Control, Communications, and Countermeasures Joint Test Force; and Chief of Modeling and Simulation and Technical Advisor to the Electronics Systems Division at the Air Force Operational Test and Evaluation Center. Her government career was preceded by university faculty positions.

Sanders received her doctorate in mathematics in 1972 as a National Science Foundation Fellow at Wayne State University and is a 1992 graduate of the Senior Executive Fellow Program, John F. Kennedy School of Government, Harvard University. She is a member of the Senior Advisory Board and a past President of the International Test and Evaluation Association (ITEA), a Fellow of the American Institute of Aeronautics and Astronautics, and a member of the Board of Directors of the Military Operations Research Society.

Modeling and Simulation (M&S) Use in the Army Acquisition Process

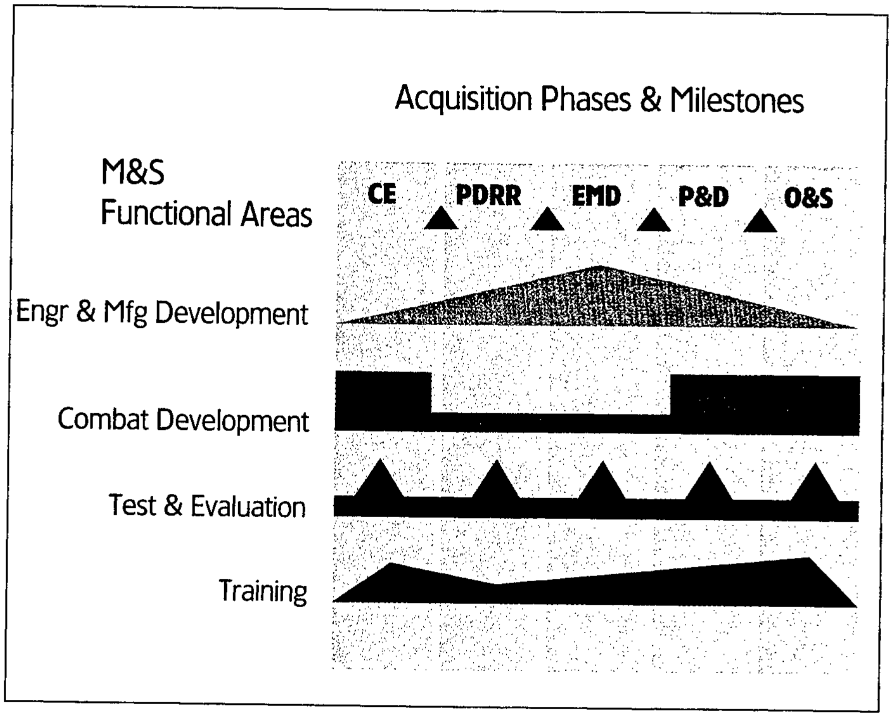
Shift to Simulation Based Acquisition Recognizes M&S As Tremendous Opportunity for PMs

DR. HERBERT K. FALLIN, JR.

A new paradigm is emerging in the Army regarding the use of Modeling and Simulation (M&S) in the acquisition process. This new paradigm is Simulation Based Acquisition (SBA). Under the old school of thought, M&S was regarded as just another tool to be used in the design of a weapon system. The shift to SBA recognizes that M&S represents tremendous opportunity for the program manager (PM) and is more than just a tool to be taken for granted. PMs today recognize that M&S must be managed as a resource in order to achieve the benefits inherent in the use of M&S throughout the acquisition process. In order to capitalize on these benefits, PMs must be savvy in two critical areas:

- What is SBA?
- Just how it is implemented?

Figure 1. **What is Simulation Based Acquisition?**



The use of M&S in the acquisition process is nothing new to the Army. What is new is the increasing availability and power of M&S tools and the decreased availability of resources for weapon system development. These two occurrences have served as a forcing function, steering the acquisition community into better integrating the use of M&S throughout all phases of the acquisition cycle, to ultimately deliver fielded systems within imposed budget constraints. When properly incorporated into a program, SBA yields the following benefits, which act to reduce risk in cost, schedule, and performance:

- Continuous evaluation of system development.
- Rapid evaluation of concept design.
- Reduce and delay need for physical prototype.
- Facilitate continuous user participation in development process.
- Efficient development/evaluation of manufacturing plans.
- Reuse of system software and hardware in training simulators.
- Ability to test proposed system at sub-component, component, and system level.

Fallin is the Director, Assessment and Evaluation, Office of the Assistant Secretary of the Army (Research, Development, and Acquisition). He holds a B.A. in Mathematics-Physics-Education from Western Maryland College; an M.A. in Mathematics from West Virginia University; and a Doctorate in Statistics from the University of Delaware. He is a an adjunct full professor at American University; a graduate of the Federal Executive Institute; and a graduate of the John F. Kennedy School of Government. Prior to his return to the Pentagon in 1993, Fallin was the Scientific Advisor to the Supreme Allied Commander Europe (SACEUR) at Supreme Headquarters Allied Powers Europe (SHAPE) in Mons, Belgium. Fallin is a 1995 Presidential Meritorious Executive.

What Is Simulation Based Acquisition?

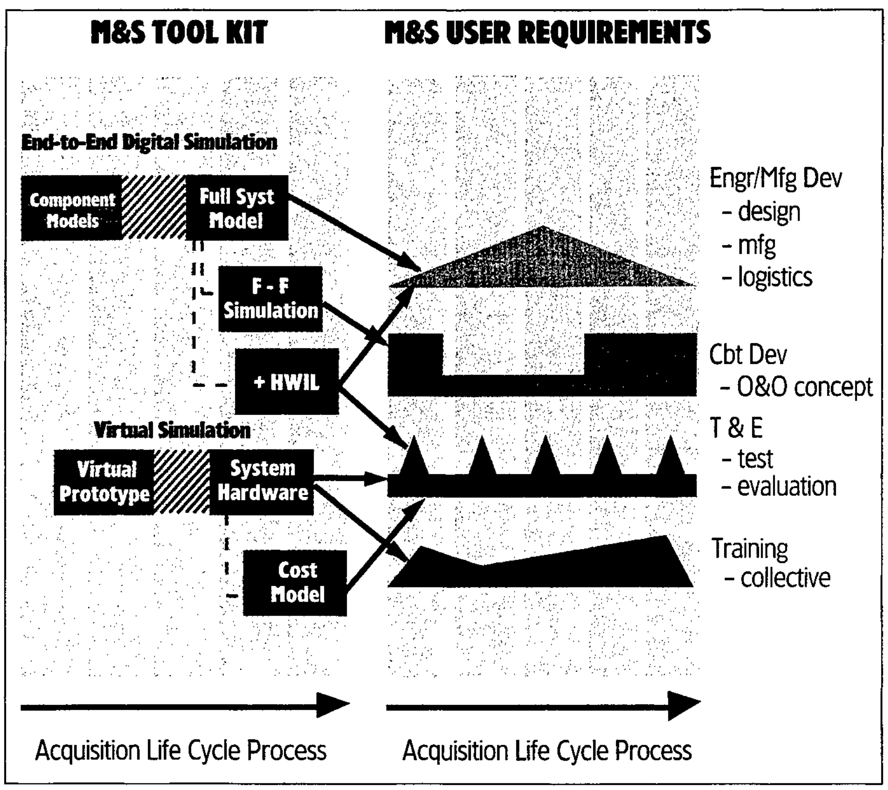
SBA is a concept for efficiently managing M&S as a resource to be exploited by the PM in the effort to accomplish acquisition objectives. As we shift toward more efficient and effective use of M&S, the abandonment of "stove-piping" techniques for employing M&S must become a reality. The boundaries imposed by the acquisition phases and milestones are no longer constraints to those who optimize the use of M&S. Re-use of M&S for multiple functions and linking different models and simulations across all phases of acquisition is a powerful concept with benefits that are currently being realized. SBA is characterized by a more flexible and integrated approach to using M&S in the acquisition process.

As depicted in Figure 1, the utility of the SBA concept to the PM lies in the notion that M&S developed for use in a functional area can serve in a similar capacity to accomplish tasks in each of the phases, from concept exploration to operations and support (O&S). Usually the M&S evolves as the program progresses until a full suite of models evolves, which represents the entire weapon system. Linking models together using one model's output data as input data for another model generates efficiencies for the PM that allow reductions in cost and schedule.

Identifying how M&S can be used across the acquisition phases and in the various functional areas represents the first step in developing the Simulation Support Strategy. This strategy focuses on the appropriate mix, type, and fidelity of M&S tools. One of the largest barriers to the effective execution of the Simulation Support Strategy in the Army was the inability to clearly articulate M&S requirements to those responsible for the actual development of M&S. To rectify this problem, the Simulation Support Plan (SSP) Guidelines, which are discussed later in this article, were introduced. These guidelines require Army PMs to craft a Simulation Support Strategy and package this strategy in a format that clearly identifies and communicates M&S requirements to the modeling community – a format referred to as the "M&S Tool Kit."

Figure 2 illustrates the mapping of M&S tools to M&S requirements. This is the essence of the SSP.

Figure 2. **Generic Top-Down Level Representation of an SSP**



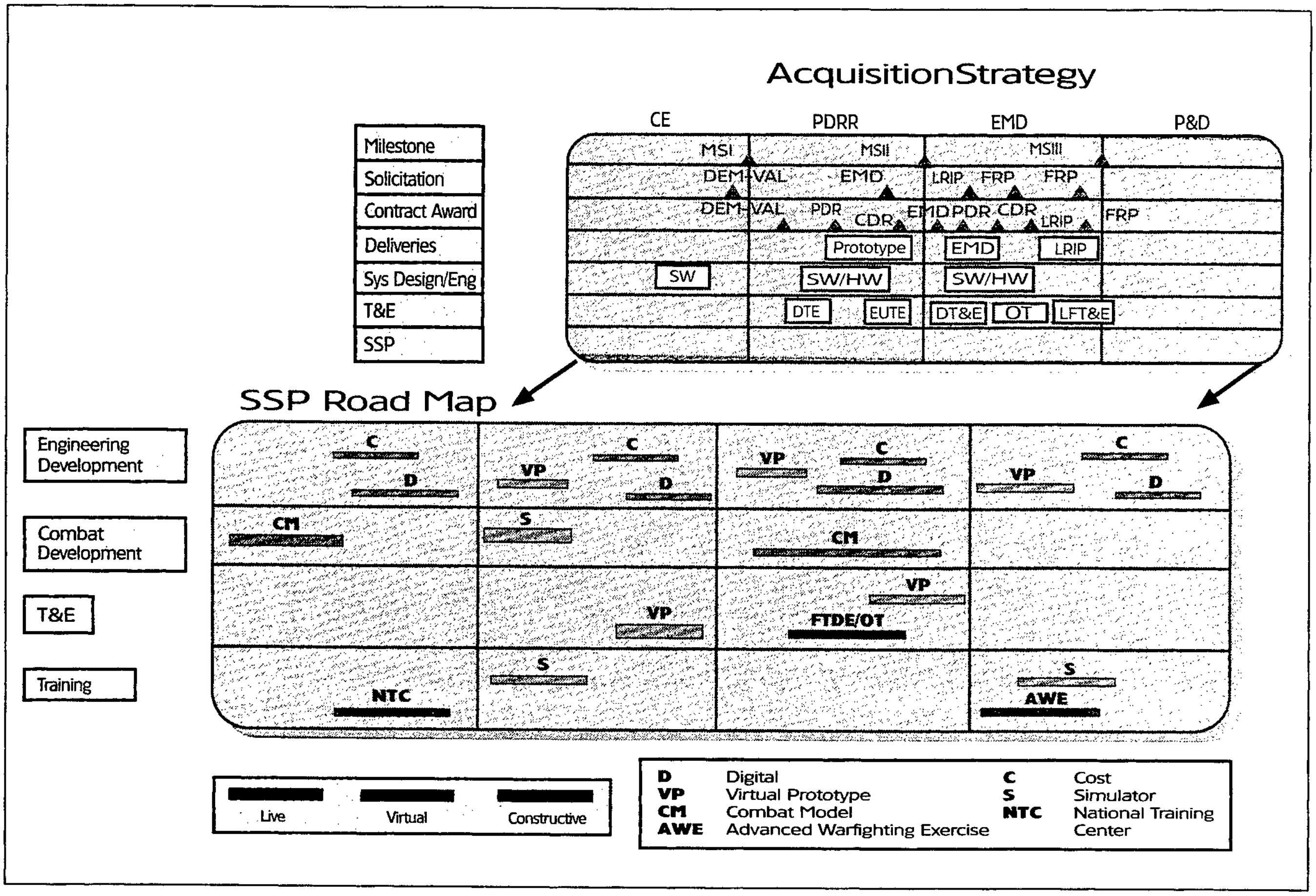
How To Incorporate SBA

The SSP is the implementing tool the Army uses to employ M&S in the most effective and efficient manner possible. This construct was initiated in 1993 by the Military Deputy to the Army Acquisition Executive. In 1996, OSD implemented a policy that required all ACAT I and II programs to coordinate their SSPs with various Army activities and include an M&S strategy summary in the Acquisition Strategy Report. The SSP Guidelines, published and distributed in May 1997, further supplemented this guidance. Additionally, in his May 2, 1997, memorandum, the Principal Deputy to the Under Secretary of Defense for Acquisition and Technology encouraged all the Services to use the Army's SSP Guidelines as a model for PMs to organize their respective M&S strategies and implement SBA.

The intent of the SSP is to provide a management tool that assists the PM in thinking through M&S requirements for the acquisition program. Additionally, the SSP provides visibility of M&S capabilities to not only the PM and supporting communities, but to other system PMs and programs in other Services. Such visibility promotes possible re-use of M&S.

The SSP, when properly crafted, conveys more than just what M&S is being used to support the program. It provides a road map to the PM, and the acquisition community, which indicates what types of M&S are required and when the M&S is needed to meet program objectives. The SSP is the vehicle that allows the PM to thoroughly integrate the use of M&S into the acquisition strategy. Figure 3 shows how the SSP road map ties in directly with the acquisition strategy.

Figure 3. SSP "Road Map" Integration with Acquisition Strategy



As indicated in the figure, the use of M&S in the functional areas occurs across all of the acquisition phases.

Just as the PM develops an acquisition strategy for the desired system, so too must the PM develop a strategy for M&S. The SSP indicates not only what M&S is required to support system acquisition, but also when the M&S should be available for use, and when and how verification, validation, and accreditation (VV&A) will be performed.

The concept of managing M&S as a resource is not always readily obvious. Typically, tools are not thought of as requiring management attention. Because of the tremendous capability of M&S to reduce cost and schedule as well as mitigate associated risk, the PM who does not actively manage M&S activities risks fielding a system that is over budget and behind schedule.

A helpful analogy in understanding why it is important to manage M&S tools is to think in terms of a do-it-yourself home project (such as building a set of storage cabinets). Anyone who has ever embarked on such a venture has a full appreciation of why the proper tools are so important. With the right tool, a daunting task can become easy. Prior to starting that home project, a set of plans is needed along with a list of required materials. The mistake many first time do-it-yourselfer's make is not realizing it is just as important to have a plan for how to use the needed tools and when to have them available. Because this is so often overlooked, time is frequently lost because the right type of tool was unavailable when needed. Work has to be interrupted to fetch the needed tool. In some cases, if prior thought had gone into identifying the best type of tool for a job (a sliding compound miter saw instead of a circular saw for instance), the job could have been accomplished in not only less time, but also with less effort and cost.

The same holds true for M&S. A PM who takes the time to identify the best set of M&S tools that can be used to accomplish needed tasks will ultimately field a better product. M&S can be used to augment the systems developers' capabilities. M&S provides the means for conducting "what if" drills when exploring new concepts or stressing a system's performance. It can also be used to identify design flaws, thus reducing and delaying the need for a physical prototype. M&S facilitates user participation in the design process so that the fielded system has increased quality, military utility, and supportability. A PM who develops and implements a well thought-out M&S strategy will end up with an improved acquisition strategy as well as a superior product in the field.

U.S. AIR FORCE NEWS RELEASE

Air Force Space Command Establishes First Space Battlelab

New Space Battlelab Will Employ Modeling and Simulation in an Operational Environment

CAPT. CLIFF D. OZMUN, U.S. AIR FORCE

FALCON AFB, COLO. A new era in warfighting was born here June 30 with the activation of the Space Battlelab, an organization dedicated to innovative space operations and concepts.

The flag of one of the Air Force's newest organizations was unfurled at the activation ceremony that was observed by Gen. Howell M. Estes III, Commander in Chief of North American Aerospace Defense Command, U.S. Space Command, and Commander of Air Force Space Command; and Col. Jeff Wenzel, the battlelab's commander.

"The Space Battlelab will be developing and examining new ways to make space an integral part, not only of what our operational warfighters do, but our logisticians, our communicators, our intelligence agencies, and eventually the American public at large," said Estes. Citing the Global Positioning System as an example, Estes said the concepts the Space Battlelab develops may result in spin-off technologies that will have application to the everyday lives of all American citizens, long after the concepts begin to serve the military's needs.

The post-Cold War environment created several new realities for the military, realities this battlelab was created to address. Foremost among those realities was the fact that Defense Department budgets and personnel numbers were significantly reduced. Combined with this was the rapid advancement

of technology development and the challenges this advancement poses for upgrading military capabilities. And finally, commercial business ventures have now replaced the military as drivers of many high-technology markets.

"The nature of the combat environment today is changing," said Wenzel. "Technology is moving faster than it ever has before. We don't know if we're applying technology that our country develops to our warfighting the way that we could or should." The military is having to fight in new, non-traditional environments such as Somalia, Bosnia, and Haiti.

"So we need to be able to change and do things differently than the way we've done them before," said Wenzel. The Space Battlelab facilitates ideas and innovation, the kind of innovation that led to many of the Air Force's historical successes.

Wenzel said the battlelab is not a "laboratory," in the classic sense. There are no test tubes, beakers or Bunsen burners. "I'd call us an innovation cell," he said.

"As we stand here today, anticipating the turn of the century, on the brink of an evolving air and space force to a space and air force, activating the first battlelab for space, we are indeed living in interesting times," said Estes. In fact, Estes said, many historic parallels exist between the birth of aviation and the birth of the space battlelab. The Wright brothers had a dream, a concept which became a reality and the foundation for the U.S. Air Force.

"These men were visionaries, visionaries whose concepts resulted in technological development which changed the course of human events," Estes said. "The need for our air and space forces are evolving and moving forward into the future at a very, very fast pace."

The Space Battlelab is one of six battlelabs founded by the Air Force whose missions are to advance the Air Force Core Competencies of: Air and Space Superiority, Global Attack, Precision Engagement, Information Superiority, Rapid Global Mobility, and Agile Combat Support. The battlelabs will rely on field innovation to identify ways to advance these core competencies.

"As the battlelabs begin to work together, the synergistic effects will lead us all into the next century and beyond, not only changing the nature of conflict but more importantly, providing new ways to make the world a safer place for all who inhabit the Earth."

"As the battlelabs begin to work together, the synergistic effects will lead us all into the next century and beyond, not only changing the nature of conflict but more importantly, providing new ways to make the world a safer place for all who inhabit the Earth," Estes said.

"We are an air and space force that embraces change in technology, and the Space Battlelab will lead the way in innovations that haven't been considered yet," said Estes. The Space Battlelab will be small and will focus on innovation for space-related Air Force Operations. It will employ field ingenuity, modeling and simulation, and existing capabilities in an operational environment in order to accomplish the Air Force mission. "The Space Battlelab offers our command and the air and space forces at large the opportunity to consider concepts that will not only further integrate space into our land, sea and air forces, but go beyond traditional methods of power protection, and most importantly, further develop space itself," Estes said.

The Space Battlelab will report directly to the Space Warfare Center here, another cutting-edge organization dedicated to marrying space-based capabilities with warfighter needs.

The battlelab will develop concepts and rapidly evaluate their potential. "We're going to take ideas from all over the Air Force and Space Command," said Wenzel. He adds that when the battlelab gets an idea that will help the Air Force execute a combat mission more efficiently, the concept will be tested and evaluated. "And then we'll run with it."

To illustrate the importance of these battlelabs, successfully demonstrated battlelab initiatives may result in changes to Air Force doctrine, new statements of combat mission needs, new Air Force requirements, reprogramming of funds, demonstrations of advanced technology concepts, or changes to ongoing or future acquisitions.

"This, of course, is the 50th anniversary year of our Air Force. And we can now see the beginnings of the space and air force of the future," said Estes. "As we embark on the next 50 years, the Space Battlelab will play a pivotal role in developing and evaluating concepts that will chart the future of military space."

The other five battlelabs are the Air Expeditionary Force Battlelab at Mountain Home AFB, Idaho; Battle Management Battlelab at Hurlburt Field, Fla.; Unmanned Air Vehicle Battlelab at Eglin AFB, Fla.; Force Protection Battlelab at Lackland AFB, Texas; and the Information Warfare Battlelab at Kelly AFB, Texas. All six battlelabs were operational by July 1, 1997.

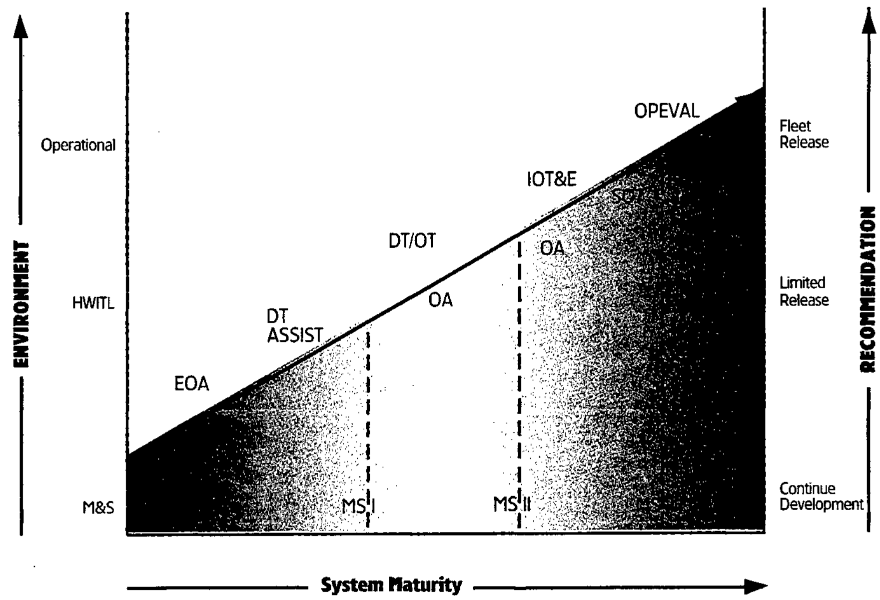
Editor's Note: Ozmun is with the 50th Space Wing Public Affairs Office, Falcon AFB, Colo.

Modeling And Simulation – A New Role for the Operational Tester

Every Ideal Test is Tempered with Constraints

STEVEN K. WHITEHEAD

The traditional role of the independent operational tester has been as the fleet users' representative in the acquisition process. It is the operational tester's responsibility to independently determine the operational effectiveness and operational suitability of a new, improved, or upgraded system prior to introduction to the fleet. This determination is achieved by testing a production representative system, in the operational environment, against the expected threat, and using fleet representative operators and maintainers. That has been the mission of Commander, Operational Test and Evaluation Force (COMOPTEVFOR) for over 50 years.



Fleet Utilization/Release Recommendation

Levels of OT&E

There are many different levels of operational test and evaluation (OT&E) conducted by COMOPTEVFOR, including developmental assist (DT Assist), early operational assessment (EOA), operational assessment (OA), initial operational test (IOT), software qualification testing (SQT), operational evaluation (OPEVAL), verification of correction of deficiency (VCD), and follow-on operational testing and evaluation (FOT&E), all of which, with the exception of DT Assist, will result in a recommendation from COMOPTEVFOR on fleet utilization or continued development. Each of these levels of operational testing (OT) involve varying levels of operational realism/fidelity, and therefore will result in varying levels of conclusions with regard to operational effectiveness and suitability as well as a fleet release recommendation. The simple rule of thumb is: The level of confidence in projected system performance during actual fleet operations is directly proportional to the fidelity of the scenario in which the test is conducted with regard to the operating environment, including both the physical environment and system maturity. The chart graphically depicts this rule of thumb.

There are two fundamental considerations for the operational tester that apply to both real-world OT and *modeling and simulation.*

Fidelity to operational environment. How representative to the operational environment is the scenario under which the data are collected? Given the constraints placed upon even real-world OT, actual test scenarios are only "representative" of how the system will be employed. The level of fidelity of a model or simulation can be compared to the level of fidelity of any real-world operational test. In real-world OT, it is not possible to conduct a test in actual combat conditions; therefore, some level of replication of actual combat is planned with as many of the variables and limitations identified as possible. This process is accepted because we test to an accept-

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able level of confidence, with the understanding that every ideal test is tempered with constraints such as funding, resource availability, technology, etc. We continually leverage all data sources to ensure the maximum use of available resources. All of this brings us to an operational test that is less than the ideal, and this is accepted and rational. Since OT is representative of fleet operations, there are always tradeoffs and resulting limitations to the scope of testing. It is anticipated that *modeling and simulation* will be an effective tool in examining those areas that have, in the past, constrained OT&E.

System maturity. Where in the development/procurement cycle is the system? Early on in the acquisition/development cycle, it is not expected that systems will be able to fully meet all of their operational requirements. Systems, as well as supporting *modeling and simulation*, are expected to mature over time, in parallel, with each successive operational test building upon the information collected previously.

It is anticipated that models and simulations used for system design will evolve and support those for initial testing, and so on. COMOPTEVFOR, working in parallel with the system developers and *modeling and simulation* proponents, will gain additional insight into how the proposed system is planned to meet its operational requirements.

Rational Interpretation and Implementation

There is no argument that *modeling and simulation* has the potential to be a highly effective and efficient tool in support of the entire DoD acquisition process and especially OT&E. It is the rational implementation of that tool which is required. The specific limiting uses of *modeling and simulation* are delineated in DoDD 5000.2-R, and their use is recommended for all Major Defense Acquisition Programs (MDAP) and Major Automated Information Systems (MAIS) programs. Common sense dictates that this approach also applies to other than MDAPs and MAIS; however, it is the interpretation and implementation of this directive where common sense plays the biggest role. The extent to which *modeling and simulation* can be used to supplement OT is generally a negotiation between the model proponent and the operational tester, and this is where the new role for the operational tester is created.

In the traditional role, the operational tester did not set requirements or thresholds for the system to be tested and evaluated, and this remains the role for systems under test. In the case of *modeling and simulation*, where users of the model/simulator are the operational testers, it is they who must aid in the definition of the performance output requirements of the model/simulation. It is the operational testers who must be satisfied with the level of validation and fidelity, as the users, to recommend accreditation of the model/simulation based on that level of satisfaction.

The directives and instructions recommending consideration of the use of *modeling and simulation* do not prescribe specifically where *modeling and simulation* should be employed. They do, however, specifically state that *modeling and simulation* cannot be used exclusively to support beyond low rate initial production decisions. Directives and instructions also do not specifically prescribe any limiting amount of developmental data that can be used to supplement OT. The decision as to the amount of "other" data (i.e., data not directly collected from an independent operational test) that are used to evaluate a system by the operational tester is the decision of the operational tester, and this includes the amount of *modeling and simulation* used to supplement operational data.

Use of Modeling and Simulation in T&E and OT

In support of the Navy and DoD Vision for the use of *modeling and simulation* in T&E, COMOPTEVFOR will continue to work to implement the advancements and improvements of the T&E process by applying *modeling and simulation* technology to –

- improve product quality and functionality;
- reduce technical risk and program cost;
- enhance performance assessments; and
- make comprehensive T&E more affordable.

To accomplish this, COMOPTEVFOR will endeavor to make significant contributions to acquisition streamlining by –

- providing test environments that can reduce acquisition life-cycle costs and time with no increase in acceptable risk; and
- enabling the developmental and operational testers to participate in the model-test-model process and integrated product team without compromising the operational tester's independence.

Specifically, one method of accomplishing this is by leveraging off of the extensive technical capabilities/knowledge within program offices to assist in OT. The use of program office resources in the understanding of system design and implementation of operational requirements will in no way compromise the independence of the operational tester.

COMOPTEVFOR has, over the past year, been highly active in exploring more efficient ways in which to use modeling and simulation to supplement OT. The majority of the endeavors to date have been in accrediting hardware/human-in-the-loop laboratories and engineering facilities. Accreditation by COMOPTEVFOR is application and use-specific. In general, verification and validation (V&V) data will be reusable to support accreditation decisions for other uses of a model or simulation. However, V&V data are also gathered against specific

rather than general requirements, and may need to be amplified for a particular application. The information needed for accreditation, and the underlying V&V processes and procedures, will vary depending upon the nature and scope of the simulation. In particular, verification, validation, and accreditation (VV&A) of federations and their associated federates is a challenge that still needs to be addressed. The VV&A agents must begin early in the development process to identify the VV&A requirements for federation models.

Involve Operational Testers Early

As Navy operational testers are not software or systems engineers but rather are operators with widely varying degrees of technical education, it is imperative that the operational testers be involved early and are sufficiently educated to understand the basic principles and uses of *modeling and simulation.* To this end, it was necessary for COMOPTEVFOR to develop a list of fundamental questions for the operational test director (OTD). The answers to these questions will assist the OTD in establishing a baseline knowledge level with regard to each modeling/simulation development and utilization.

Q

What is the reason for the initial development of the model, and what is its similarity to the current application? Is there a requirements document for the model and a software design specification for the initial implementation and for any modifications?

Q

What is the developer's reputation, Software Engineering Institute rating, and model development experience? Can the developer provide metrics on software maturity, complexity, requirements traceability, design stability, and depth and breadth of testing?

Q

What are the hardware, software, personnel, data, and security requirements associated with using the model? What is the schedule for model development and model V&V activities?

Q

What is the configuration management (CM) status of the model and its associated databases? Does the CM process have these four characteristics: (1) a well-defined baseline; (2) standard baseline test cases and data sets; (3) well-defined, coordinated, and supported testing program; and (4) current, thorough documentation?

Q

What V&V has been accomplished, or is planned, to establish model credibility?

Q

What modeling and simulation documentation is available (types of documentation, detail, accuracy, and currency)?

Q

What are the known limitations or problems with the model? (A good configuration management system has such a list readily available.)

Operational Testers do not "test" or verify models or simulations. They are, however, closely involved in the validation process. The Draft COMOPTEVFORINST 5000.X establishes procedures on the use of models to support OT&E and describes the information necessary for accreditation by COMOPTEVFOR. It is the model proponent's responsibility, in conjunction with COMOPTEVFOR, to –

- develop plans to use *modeling and simulation* in OT, which includes a description of the system, test objectives, *modeling and simulation* objectives, and a test schedule;
- develop V&V to support accreditation for the application; and
- provide a V&V plan, V&V reports, and other support documentation, such as model user guides, analyst notebooks, configuration management plans, software development policy and procedures, and software process review reports.

The accreditation package contains at least the minimum documentation required by DoD 5000.59P and Draft SECNAVINST 5200.XX.

Conclusions

As a tool to supplement for limited assets, it is COMOPTEVFOR policy that the *modeling and simulation* will not replace actual operational assets. *Modeling and simulation* is a tool to more effectively and efficiently employ the limited assets available. *Modeling and simulation* should not be used to extrapolate system performance. The Navy's Draft Test and Evaluation Modeling and Simulation Master Plan includes the documentation requirements, with formats, for the use of *modeling and simulation* in OT. The accreditation plan format, accreditation report format, and verification and validation report format are suggested formats and can be tailored to each application.

While OT must remain "operational," *modeling and simulation* can be used very successfully in test planning, rehearsals, training, post-test analysis, and in limited cases, the test itself. Specific guidance on when *modeling and simulation* can be successfully applied cannot be a cookbook approach. Each program must examine the testing areas that could be more effectively executed using *modeling and simulation.* In some cases, the use of *modeling and simulation* may be more expensive than traditional testing, but yield results that would be impossible to obtain using traditional testing. In all cases, the decision makers and the operational testers must assess the value added by *modeling and simulation* and determine the most cost-effective testing plan.

Operational testers must continue to participate in the *modeling and simulation* initiative that will form the basis for future use of emerging technologies to ensure OT&E specific issues are incorporated. Additionally, an aggressive effort must be made to identify and use the full capability of *modeling and simulation* within OT&E.

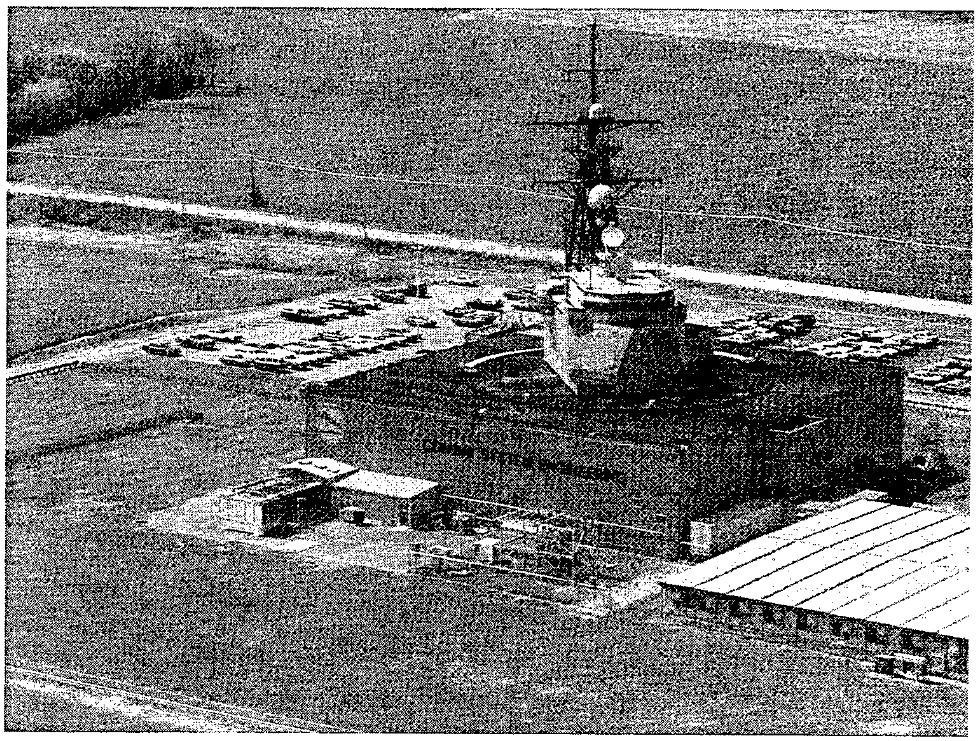
SPY-1D(V) Models and Simulations Support Operational Testing in a Remote New Jersey Cornfield

PEO, Developer, Operational Tester Combination Works Smarter, Placing Best Technology in Warfighters' Hands

LT. CMDR. HARRY M. CROYDER, U.S. NAVY
CMDR. WILLIAM P. ERVIN, U.S. NAVY • DR. DAVID S. MAZEL

Accredited models and simulations make land-based testing of the SPY-1 radar family more credible than ever before. This article is about one such operational radar test, conducted in a remote New Jersey cornfield.

Also in this article, we explain the verification, validation, and accreditation of the SPY-1D(V) program models and simulations, and how this process not only ensures the proper use of high-fidelity, thoroughly understood models and simulations, but also enhances the realism and credibility of operational testing. Further, we describe development and application of this accreditation process in support of the recent SPY-1D(V) radar test; focus on the managerial versus the technical aspect of this process; and present potentially useful ideas to organizations involved with modeling and simulation in the operational test and evaluation arena.



AEGIS Combat System Engineering Development Site (CSEDS), Home of the "Cornfield Cruiser"

Photo courtesy Unisys Corporation

Navy's SPY-1D(V) Strategy Decision

In 1994, the Navy faced an important acquisition strategy decision – important because the AEGIS SPY radar system is completely integrated into the AEGIS ship, and it takes five years to build a ship. Two options emerged for consideration:

Option 1. Produce and install a single SPY-1D(V) radar in a new construction DDG 51-class ship.

Option 2. Use the land-based test site to test operationally the engineering development model of the SPY-1D(V) radar.

Croyder is a surface warfare officer with over 19 years of service. He is currently assigned to Commander, Operational Test and Evaluation Force (COMOPTEVFOR), Norfolk, Va., as the operational test director for all AEGIS programs. Ervin is a surface warfare officer, currently assigned as section head for surface-to-air missiles at COMOPTEVFOR. Mazel is a research analyst for The CNA Corporation, Center for Naval Analyses. He holds a Ph.D. and is currently on temporary assignment to COMOPTEVFOR.

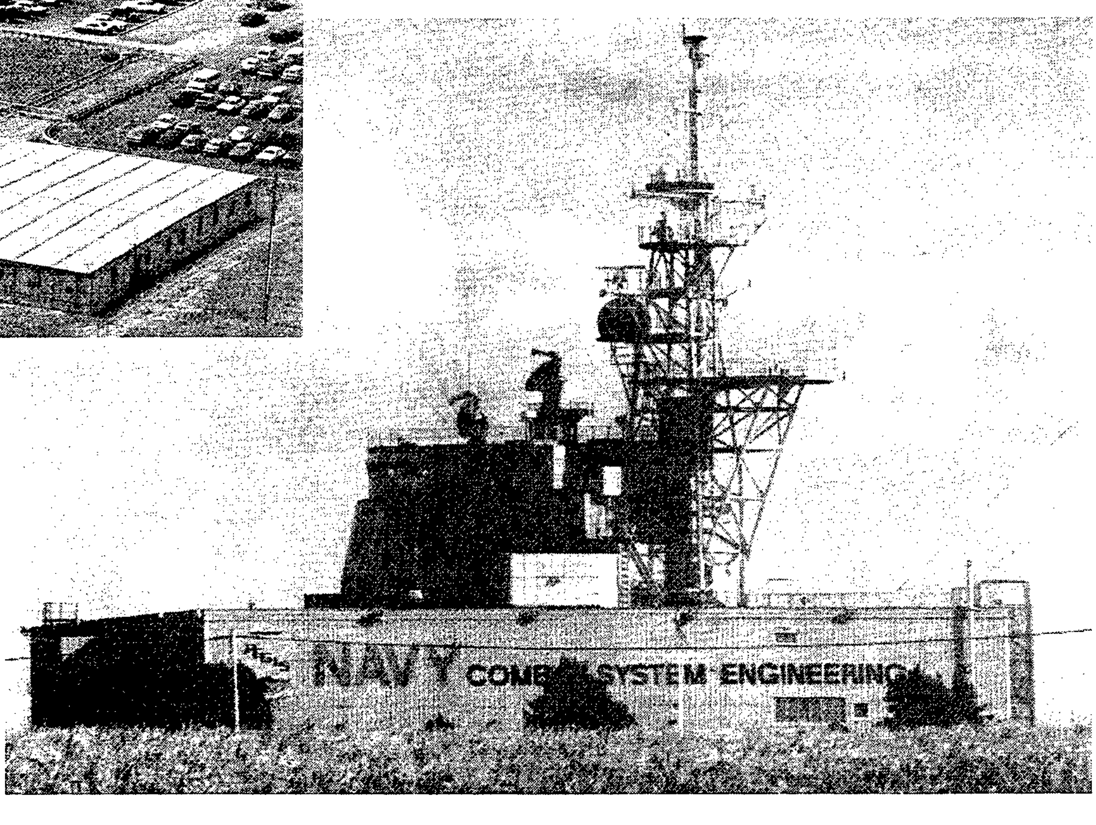
Option 1 would cause the interruption of SPY-1D radar production and create a unique operational ship for the sole purpose of at-sea testing to support a low-rate initial production acquisition decision. This option would have the advantage of testing in the operational environment, but the disadvantage of delaying fleet introduction of SPY-1D(V) radars for up to five years and incurring additional costs for creating a unique asset and conducting two SPY-1D(V) production starts versus one.

Option 2 called for land-based testing to support a low-rate initial production acquisition decision without interfering with current radar/ship production. This option had the advantage of making the acquisition decision in 1996 vice 2003-plus, but the disadvantage of testing in a land-based operating environment.

Key to the Navy's SPY-1D(V) strategy decision was a determination that land-based testing was adequate to support a low-rate initial production decision. Toward that end, the Navy planned to conduct this land-based testing at its Combat Systems Engineering Development Site (CSEDS) in Moorestown, New Jersey. Due to its land-locked location, CSEDS' characteristics are vastly different from any shipboard environment, and those differences remained to be assessed.

The CSEDS facility is 50 miles from the Atlantic Ocean in a location that prohibits low-flying aircraft and severely restricts chaff and electronic jamming activities. Any test scenarios involving fixed wing aircraft, helicopters, chaff, and jamming must be conducted in areas that do not interfere with commercial airways, nearby subdivisions, or local farm animals. Site characteristics bear little resemblance to the at-sea operating environment of dynamic sea clutter, multipath low elevation propagation, and pitching and yawing conditions a radar will operate in when installed in a Navy ship. The testing methods for SPY-1D(V)'s new capabilities were all adversely impacted by CSEDS' site limitations.

To help make the test adequacy determination, the Assistant Secretary of the Navy (Research, Development, and Acquisition) (ASN[RDA]) commissioned an independent advisory committee to investigate the SPY-1D(V)'s capabilities and CSEDS characteristics. After assessing risk mitigation, technical risks, and test adequacy, this independent committee concluded that, with the use of models and simulations, the radar could be tested well enough to support the low-rate initial production decision. Based in part on this conclusion, ASN(RDA) chose Option 2 and signed an Acquisition Decision Memorandum authorizing land-based operational testing at CSEDS.



SPY-1D(V) Radar. The AEGIS SPY radar system is completely integrated into the AEGIS Destroyer Fleet.
U.S. Navy photo.

ASN(RDA)'s decision complemented the growing trend within the Department of Defense (DoD) to find alternatives for the ever-increasing costs and rapidly shrinking resources associated with test and evaluation requirements, particularly requirements associated with field tests. One alternative is the use of models and simulations. DoD has moved toward models and simulations as a way to cut expens-

es in developmental and operational testing. Real-world assets such as very small targets, aircraft services, and missile firings are becoming increasingly scarce and expensive. Some acquisition programs have been using models and simulations for years and have established methodologies for conducting verification and validation.

The Verification, Validation, and Accreditation Process

To the Navy's independent test agency – Commander, Operational Test and Evaluation Force (COMOPTEVFOR) – the idea of using models and simulations instead of actual field operations to validate at-sea systems' performance was a departure from traditionally accepted testing methodology. To the COMOPTEVFOR staff, who experienced and well understood at-sea realities, the modeling of the SPY-1D(V)'s new capabilities for operational applications had little credibility because CSEDS is land-locked.

COMOPTEVFOR supported the move toward models and simulations by developing a command concept and procedure that outlined how models and simulations fits into operational testing. Involving a process called verification, validation, and accreditation, this concept calls for a program executive office to verify and validate all the models and simulations it requires to perform necessary developmental and engineering tests. Ideally, the verification and validation process should satisfy the program executive office that the selected models and simulations function as expected. When the program executive office is satisfied, it formally accepts the models and simulations for use in developmental testing. This formal acceptance is called certification, and is the measure of the program office's confidence in its model. After certification, the program executive office directs the model's use in the developmental test strategy. If the models and simulations will be used in an operational test, COMOPTEVFOR must accredit the models and simulations for a specific purpose within that test. Accreditation is the COMOPTEVFOR formal acceptance of the validated models and simulations. COMOPTEVFOR always considers certification a prerequisite to accreditation.

Step 1. The Simulation Management Plan (SMP). Neither the Program Executive Office Surface Combatants-AEGIS Program (PEO SC-AP) nor COMOPTEVFOR possessed the experience or the infrastructure to support any of the new models and simulations initiatives, including verification, validation, and accreditation. Some of the basic concepts were there such as certification and accreditation, but few of the real-world mechanics. Those mechanics had to be created.

As the first step, we found a working models and simulations organization. As a result of using models and simulations for years, the Tomahawk Cruise Missile Program possessed practical experience, which it willingly shared. The PEO SC-AP and COMOPTEVFOR staff members, however, faced the daunting task of mastering the Tomahawk methodology; the COMOPTEVFOR verification, validation, and accreditation instruction; the program executive office and COMOPTEVFOR goals; and the time and financial constraints on the entire process. Once they digested all these elements, the program executive office and COMOPTEVFOR staffs jointly authored a verification, validation, and accreditation plan, called the SPY-1D(V) Radar System DT/OT Simulation Management Plan (SMP).

First SMP Component – The Goals

The establishment of goals by each participating office is the first component of the SMP. Once established, each office must clearly understand the goals of all other offices and jointly design a framework that will mutually support the achievement of all goals.

Accreditation of those models that supported its mission – the operational test – was COMOPTEVFOR's primary goal. In this case, accreditation required seven models/simulations/simulators/stimulations. Only after a thorough review of the verification and validation process to determine the fidelity of each model in supporting operational testing, was accreditation awarded. Prior to accreditation, we prepared and reviewed the following required documents for each model (discussed at length in subsequent paragraphs):

- Simulation Validation Plan
- Simulation Validation Report
- Simulation Version Description Document
- Program Executive Office Certification

No requirement exists that any model must exactly replicate the real world; in other words, no model is expected to be a "perfect" empirical representation.

Alternately, one of the program executive office's major goals was the accreditation of its models and simulations. Accreditation meant that the SPY-1D(V) models and simulations were credible enough to conduct the test strategy outlined in ASN(RDA)'s Acquisition Decision Memorandum. Accreditation also meant that an outside activity reinforced the program executive office's reputation for enforcing standards. Since certification was a prerequisite to accreditation, the SMP outlined the program executive office's certification requirements as well.

Second SMP Component – Verification and Validation Method

The other major component in the SMP is the actual verification and validation execution framework. The preferred, overarching theoretical concept of verification and validation calls for a disinterested third party to accomplish validation. This type of validation is known as independent verification and validation. For the SPY-1D(V), nei-

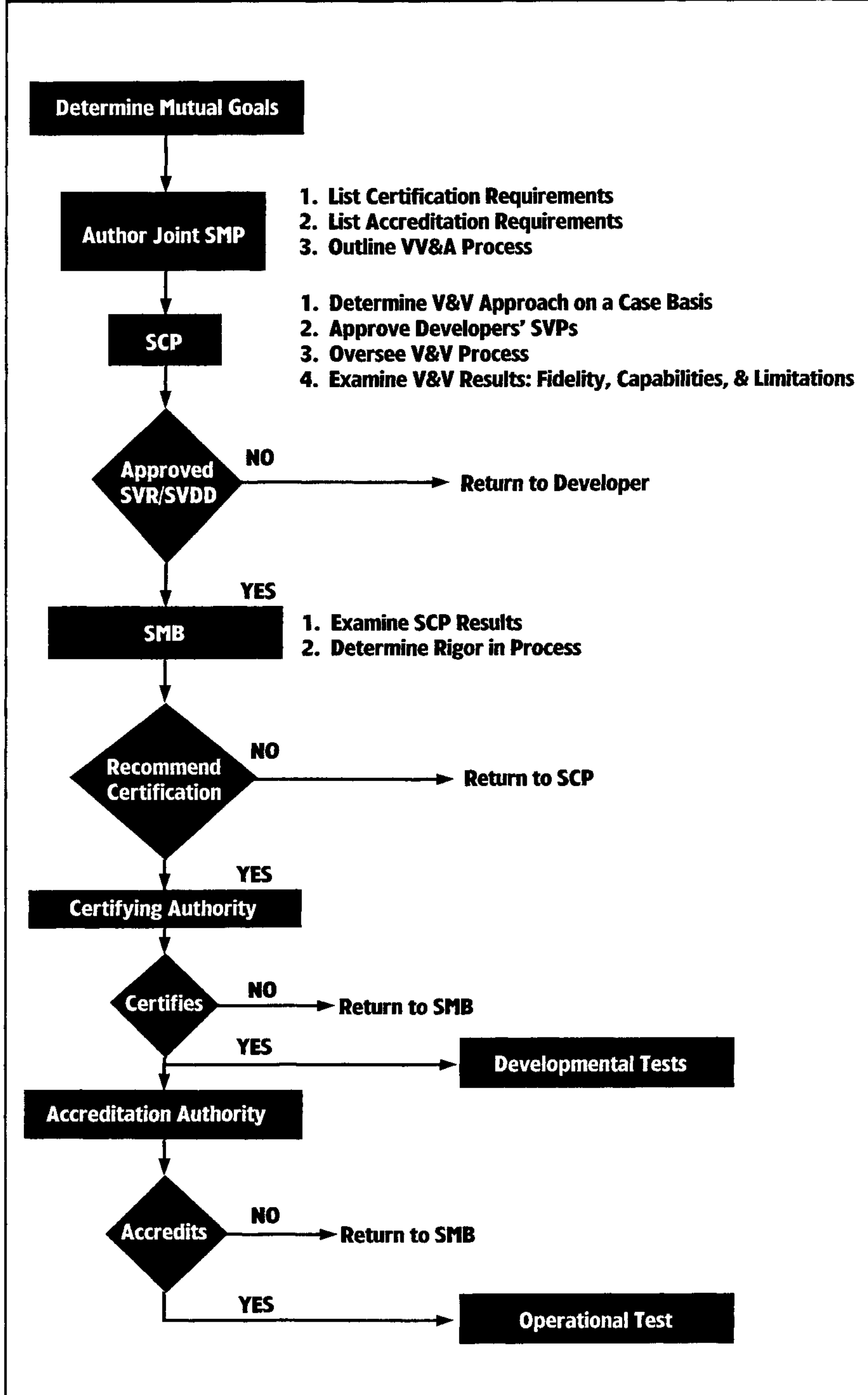
ther the time nor the money existed to contract such a party to independent verification and validation – all seven required models and simulations. Instead, the SMP authorized an internal verification and validation method, the use of which represented a need to mitigate any credibility risk to the program. This meant that the models and simulations developers would validate their own models with program executive office and COMOPTEVFOR oversight instead of independent verification and validation.

Again, in the interest of time and money, the SMP did not require new data collection. In other words, for certain models the developers were not tasked to acquire new empirical data to support verification and validation. New collection and analysis of atmospheric propagation, sea clutter, or live missile telemetry data was impractical. This information already existed in several places and could be used at significant time and cost savings.

Third SMP Component – Credibility
Next, PEO SC-AP and COMOPTEVFOR agreed that their staffs must maintain ruthless self-discipline to reduce risk and ensure credibility since independent verification and validation would not be used. All verification, validation, and accreditation procedures, results, and discussions would be open to outside agencies' inspection. This openness philosophy was the cornerstone of the entire effort's success.

Fourth SMP Component – The Framework
Finally, the SMP provided the organizational structure to achieve the goals and execute the verification and validation method. This structure consisted of the Simulation Management Board (SMB) and the Simulation Control Panel (SCP). The SMP required the use of the SMB and the SCP and provided an executive summary of their functions. The SMP also described each one's membership and its role in accomplishing certification and accreditation.

SPY-1D(V) Accreditation Process



SMP	Simulation Management Plan
VV&A	Verification, Validation, and Accreditation
SCP	Simulation Control Panel
SVR	Simulation Validation Report
SVDD	Simulation Version Description Document
SMB	Simulation Management Board

Step 2. The Simulation Control Panel (SCP). The SCP provided the working technical oversight of the verification and validation process. Its composition included mainly technical personnel, who well understood their respective models and simulations, as well as AEGIS combat system technical representatives. Part of the SCP's function was to promote a technical exchange.

The SCP – Its Membership

The SCP's chairperson was the SPY-1D(V) program manager's assistant. The co-chairperson was the COMOPTEVFOR operational test director for the SPY radar program. These two individuals directed the oversight process. It is important to note that both co-chairpersons had to be in agreement for any item to pass the SCP. Other members included technical representatives from the three companies who developed the models and simulations, namely Lockheed Martin (Government Electronic Systems) Corporation, Technology Service Corporation, and Systems Engineering Group. Additionally, the Naval Surface Warfare Center and AEGIS Technical Representative provided technical support to the program executive office chairperson, and the Center for Naval Analyses supported the COMOPTEVFOR co-chairperson.

The SCP – Its Function

As previously mentioned, the SCP's charter was to perform the working-level oversight of the verification and validation process. Toward that end, the membership devoted a good deal of time and effort to understanding and defining the seven models and simulations. When the SCP leadership believed they achieved a sufficient understanding of each model and simulation, they asked the developer to propose a verification and validation plan based on its assets and the data available. When the developer eventually submitted a proposal, the membership then discussed it at length and selected the actual process the developer would use to validate the models and simulations.

"When the SCP leadership believed they achieved a sufficient understanding of each model and simulation, they asked the developer to propose a verification and validation plan based on its assets and the data available."

Most of the early meetings centered around selecting the proper verification and validation method. Sometimes these discussions were rather frank and resulted in some strong disagreements, but fortunately the SMP did not require unanimity. Once the co-chairpersons accepted the validation proposal, the developers proceeded to write the Simulation Validation Plan. The SCP met frequently to monitor validation progress. Sometimes, of necessity, the SCP changed verification and validation procedures because the developer found a better way or discovered the current method wasn't working as planned. The SCP membership carefully reviewed validation progress and early results to ensure they met the objectives initially outlined in the SMP. As verification and validation progressed, the developers began to write the Simulation Validation Report and the Simulation Version Description Document.

The Simulation Validation Plan

Groundwork. The SMP required a separate Simulation Validation Plan for each model and simulation. As previously noted, early SCP meetings centered around determining which verification and validation method to employ for each model and simulation. During those determinations and in order to author the Simulation Validation Plan, several questions remained to be answered, or at least addressed:

Is the model and simulation a model? (A model is defined as a physical, mathematical, or otherwise logical representation of a system entity, phenomenon, or process.)

Is the model and simulation a simulation? (A simulation is defined as a method for implementing a model over time, or where real-world and conceptual systems are reproduced by a model.)

For what purpose will the model and simulation be used?

What are the capabilities and limitations of each model and simulation?

What value will the model and simulation add to the operational test?

How will use of each model and simulation impact the operational tester's ability to formulate conclusions?

How does the model interoperate with the other six models?

What options exist within the time/money/data constraints to verify and validate each model?

In practice, the SCP answered some of these questions only after they approved the Simulation Validation Plan, and the interoperability issue was never completely addressed. The SCP intended the verification and validation process to be flexible. When the panel found a better way, they altered the process and sometimes changed an answer too. Once the SCP assembled sufficient information, it addressed requirements for the Simulation Validation Plan.

Two Simulation Validation Plan Requirements. The first Simulation Validation Plan requirement was the selection of the right method based on the SCP's understanding of the models and simulations . As a result, the SMP mandated that the verification and validation process use at least one of three possible methods:

- Model-to-Real-World Comparison
- Model-to-Model Comparison
- Code Analysis

For SPY-1D(V), a model-to-real-world example was the simulation that represented small radar cross-section targets. Because no real-world targets existed, the developer used the model-to-real-world simulation, attaching a physical sphere to a balloon and launching it into the air. This sphere had a known cross-section that fluctuated in the real environment. As it floated away, the SPY-1D(V) radar tracked the sphere. It also tracked a target simulation constructed with the same cross-section. Unlike the sphere, however, the target simulation possessed no cross-section fluctuating capability. We then compared the sphere's cross-section, as observed by the radar, to the simulation's cross-section as observed by the radar. Results determined the corrective action necessary to improve the simulation.

A model-to-model example was the sea clutter simulation. We used this simulation because CSEDS is a long way from the ocean. The simulation was actually a composite of two models and simulations – a mathematical model, representing the sea clutter phenomenon; and a hardware generator, which implemented the model into the system such that the radar could observe the sea clutter. Validation of the generator's implementation ability compared the mathematical model with the generator's simulation. The results initiated a plan of action.

The second requirement stipulated that the known capabilities and limitations of the models and simulations be stated. Every Simulation Validation Plan included a list of the known capabilities and limitations of its model to preclude future misunderstandings. The unforeseen benefit of this requirement was the discovery that the "known" capabilities and limitations listed in the Simulation Validation Plan were not necessarily the same ones revealed later during verification and validation.

As verification and validation progressed, the SCP began to author the next two required documents, the Simulation Validation Report and the Simulation Version Description Document.

The Simulation Validation Report
The Simulation Validation Report was the written report of results achieved during verification and validation. It contained an executive summary and a technical analysis section. Included in the Simulation Validation Report were validation details such as –

- a description of the actual validation procedure;
- a discussion of why that procedure differed from the one outlined in the Simulation Validation Plan; and
- a list of capabilities and limitations confirmed by the verification and validation. Where the Simulation Validation Plan and Simulation Validation Report lists differed, the developer added an explanatory note.

The Simulation Version Description Document
The Simulation Version Description Document briefly described the computer program configuration management that supported the models and simulations. The developer met this SMP requirement chiefly through a related, non-accreditation event called a COMOPTEVFOR Software Quicklook. A Software Quicklook provided COMOPTEVFOR with a basic understanding of a developer's software management program.

The program executive office had previously encouraged the conduct of a Software Quicklook to promote COMOPTEVFOR's understanding of configuration management issues. A thorough review of the Quicklook confirmed that the prime developer followed accepted software configuration management procedures, further increasing COMOPTEVFOR's confidence in the models and simulations. Since the Quicklook is not a verification, validation, and accreditation requirement, it did not eliminate the accreditation requirement for a Simulation Version Description Document. However, using Quicklook data, the SCP could streamline the document.

Now verification and validation was complete. The SCP had written a Simulation Validation Plan, and the developers had executed it. The approved Simulation Validation Report contained an executive summary and the technical results. The Simulation Version Description Document was complete.

The co-chairpersons agreed to move the verification, validation, and accreditation process forward. The next step was to convene the Simulation Management Board.

Step 3. The Simulation Management Board (SMB). The SMB was a four-

member board, chaired by the SPY-1D(V) program manager. Its purpose was to recommend certification to the program executive office certifying officer. Prior to recommending certification, it evaluated the Simulation Validation Reports provided by the SCP. The SMB voting members were the chairperson, the PEO SC-AP models and simulation division head, and an AEGIS Technical Representative senior staff member. The COMOPTEVFOR Assistant Chief of Staff for Surface Warfare acted as the single, nonvoting advisory member.

The SMB acted to satisfy its membership that the verification and validation had been rigorously executed. In that regard, the board consulted the COMOPTEVFOR advisory member for the accreditation authority's perspective on the verification and validation results. When the vote was unanimous, the board forwarded a certification recommendation to the proper authority at the program executive office. When the vote was not unanimous, the board returned the product to the SCP for additional work.

The SMB/SCP membership intended their proceedings to be an open process. Interested parties from the Director, Operational Test and Evaluation and the Institute for Defense Analyses had a standing invitation to attend either board/panel. The membership extended this standing invitation for two purposes:

- Without specific DoD guidance, the SPY-1D(V) joint verification, validation, and accreditation effort was somewhat "experimental." Agencies closer to DoD might be able to provide additional perspectives on the future evolution of models and simulations policy.

- The demonstration of the rigorous, disciplined process should be witnessed and not merely advertised.

Step 4. Certification and Accreditation The SMB chairman briefed the certifying authority on the results and recommendations of the SMB. This authority certified the recommended models and simulations when convinced that the SMB had applied the requisite tough examination required by the SMP tenet of self-discipline. After the program executive office completed its internal administration, the certifying official then sent an official letter of certification to the accreditation authority.

Upon receipt, the OPTEVFOR operational test director briefed the accrediting officer on the certification letter. Included in the brief was a synopsis of the technical details from each Simulation Validation Report, including capabilities and limitations; the intended use of the models and simulations in the operational test; and an assessment of whether the ability to draw conclusions was affected. The brief also discussed how well the developer met COMOPTEVFOR requirements, and then provided recommendations. COMOPTEVFOR accredited the models and simulations when convinced that the program executive office/COMOPTEVFOR/developer working team had satisfactorily executed its charter.

The operational test director was now able to complete the test plan, obtain its approval from the appropriate authority, and conduct the operational test. Afterwards, the data analysis, final report, and test results briefings relied heavily upon the verification, validation, and accreditation effort.

Future Challenges

The successful achievement of certification and accreditation for the operational test did not mean the end of the SPY-1D(V) validation, verification, and accreditation process. As expected, the subsequent briefings provided to PEO SC-AP, COMOPTEVFOR, and the Director, Operational Test and Evaluation resulted in feedback. Thus, some new challenges arose:

- Expand existing databases by collecting new empirical real-world data.

- Refine models and simulations fidelity, such as the sea clutter mathematical model, to more closely approximate real sea clutter.

- Increase the capabilities of essential models and simulations, such as incorporating a fluctuating radar cross-section behavior in the simulated targets.

- Overcome certain limitations, such as the sea clutter generator's inability to implement fully the sea clutter model.

- Improve the verification, validation, and accreditation process.

- Investigate new models and simulations that will add value to future developmental and operational tests.

Lessons Learned

In reality, the functioning of the verification, validation, and accreditation process was not nearly as clean or linear as outlined in this article. In some cases, the developer wrote the Simulation Validation Plan and the Simulation Validation Report concurrently; for example, if a validation procedure proved impractical halfway through, and another method had to be implemented. In other cases, a model's verification and validation yielded an unexpected result. Once we found that a model intended for use displayed an undesired, less-realistic effect when compared to other industry models. Ultimately, we discarded this model and selected a substitute. For reasons like these, the SCP was educational for all its members.

We continued to assimilate lessons learned throughout the course of this verification, validation, and accreditation process. A brief description and solution for three of these lessons follow:

Lesson 1
We originally constructed the SCP as a voting body, similar in makeup to the SMB. However, at this level a simple majority vote consisting of the three developers and/or a supporting organization could theoretically override the desires of either the program executive office or COMOPTEVFOR. The SMP had obligated the program executive office chairperson and COMOPTEVFOR co-chairperson to support mutually the plan's common goals. For either individual to proceed without the complete concurrence of the other was self-defeating, regardless of developers' positions. So in practice, voting was irrelevant and ultimately eliminated; a simple agreement between chair and co-chair moved the SCP forward.

Lesson 2
Only one SCP existed for all seven models and simulations. The Tomahawk Program's original concept of one SCP per model was good, but considered impractical for SPY-1D(V) because of time and money constraints. So, each SCP meeting addressed all the concerns and problems associated with each model and simulation. As test time drew near, with much left to do, this "do-everything-at-SCP-meeting" approach failed. The SCP could not efficiently handle all the requirements of Simulation Validation Report development for seven models. Simulation Validation Plan writing turned out to be much more challenging and controversial than anticipated. The SCP eventually became so inundated, a permanent session appeared necessary.

The solution was to break up the SCP into smaller teams that each dealt with a subset of Simulation Validation Reports. This allowed the available expertise to focus more completely and exactly than before. One team's membership consisted of two Lockheed Martin experts as well as representatives from the Naval Surface Warfare Center and Center for Naval Analyses. Another team included an AEGIS Technical Representative staffer, a Lockheed Martin engineer, and an OPTEVFOR analyst. Representation on each team also included the program executive office and COMOPTEVFOR. When a team wished to present a viable product, the membership convened the formal SCP.

Lesson 3
The honesty and integrity of all the participants in the verification and validation process was absolutely vital to its credibility. The co-chairing offices hid nothing from external observers, including some rather high-spirited controversies. One developer immediately revealed a model's limitation, newly discovered during verification and validation, that impacted unfavorably on its use. To their credit, the supporting activities focused their attention on problem solving, not just problem noting.

Conclusion

The net result of this rather involved process had several positive elements. All parties learned that a model's legacy is not sacrosanct. We uncovered preexisting, unknown capabilities and limitations that led to a more precise use of the models and simulations and a more accurate interpretation of test data. Ultimately, we achieved a high degree of confidence in the capabilities as well as the limitations of the models and simulations. The program executive office and its developers also gained fresh insight about their models and simulations and how to improve them.

And finally, COMOPTEVFOR authored an operational test plan that realistically and fairly tested the radar at CSEDS. ASN(RDA)'s acquisition strategy worked as intended, and the Navy saved a lot of time and money. Common sense and teamwork made this process viable and successful. DoD will see more of these efforts in future programs as the program office/developer/operational tester combination works smarter to place the best technology available in the hands of the warfighter.

NEW GUIDEBOOKS AVAILABLE!

The *Indirect Cost Management Guidebook* is now available from the DSMC Distribution Center by faxing a request on official agency letterhead to Jeff Turner, (703) 805-3726, DSN 655-3726.

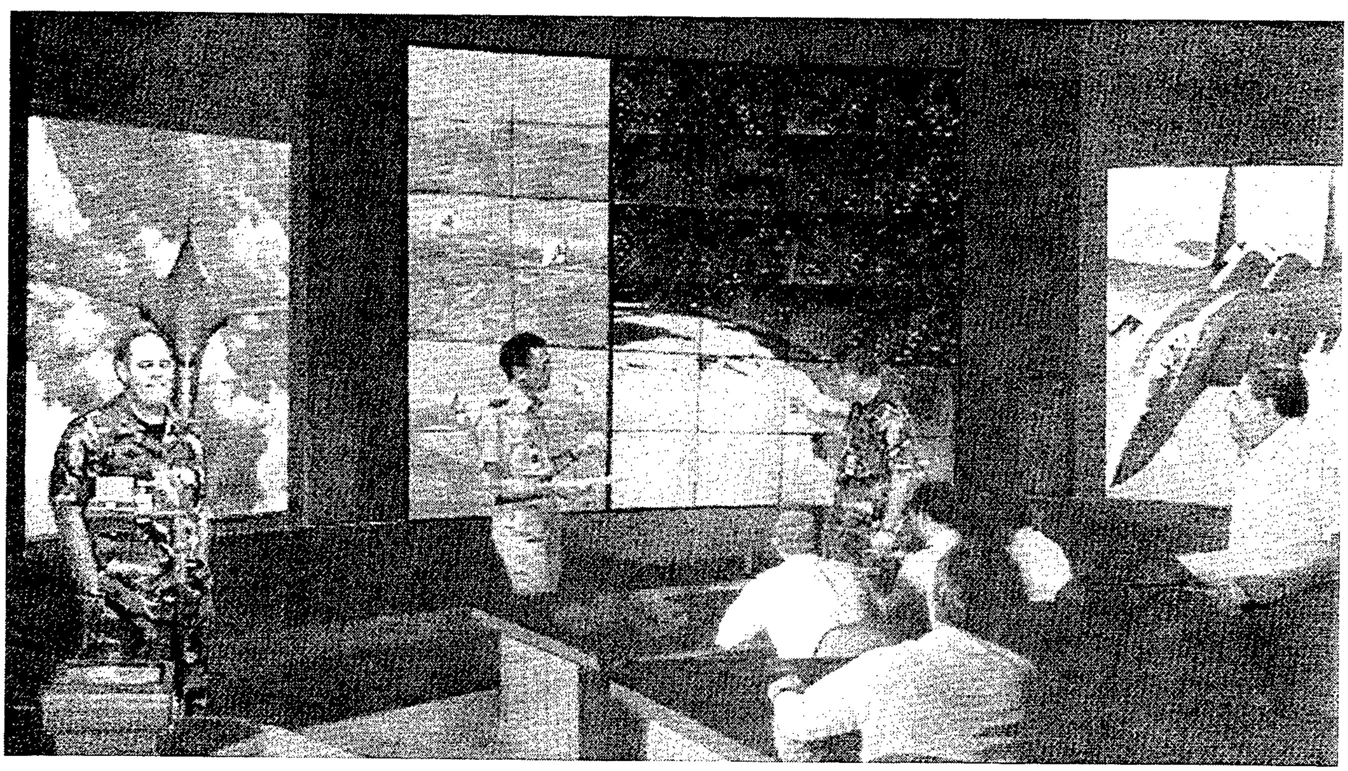
A limited quantity of the guidebook, *Program Manager's Tool Kit*, used in the Advanced Program Management Course, is now available from the DSMC Press by faxing a request on official agency letterhead to Carrie Simpson, (703) 805-2917, DSN 655-2917.

Put a Virtual Prototype on Your Desktop

An Air Force Collaborative Research and Engineering Environment for Acquisition Reform

WILLIAM K. MCQUAY

Are you tired of reading statements of work, technical specifications, proposals, and monthly reports? Have you asked yourself, what does this proposal really mean? What is the contractor actually saying, or more importantly, what will the deliverable really be able to do? Or perhaps you've indulged in a little wishful thinking: If I could only reach out and touch the new system before it exists and do a

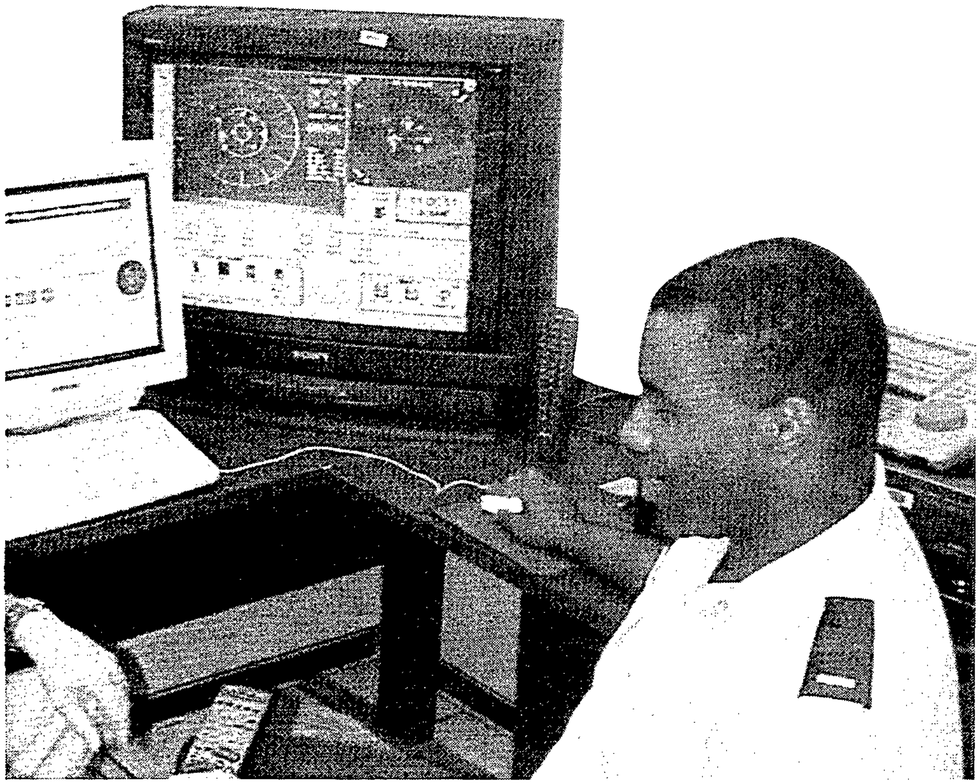


VIRTUAL REALITY BATTLEROOM FOR THE JOINT SYNTHETIC BATTLESPACE — A "VIRTUAL PHOTO" OF A "VIRTUAL FACILITY." AN ARTIST'S CONCEPT OF THE IMMERSION THEATRE TO DEMONSTRATE FUTURE TECHNOLOGY AND WEAPONS SYSTEMS USING SIMULATION AND VISUALIZATION. THE PHOTO IS ACTUALLY A DIGITAL ENHANCEMENT OF TWO PHOTOS DEPICTING THE INSIDE OF THE DOD WARBREAKER FACILITY IN WASHINGTON, D.C.; THE FACES REPRESENT PEOPLE WHO ACTUALLY WORK AT WRIGHT LABORATORY.

McQuay is Chief, Simulation Technology Branch, System Concepts and Simulation Division, Avionics Directorate, U.S. Air Force Wright Laboratory, Wright-Patterson Air Force Base, Ohio. He directs the Electronic Concepts Simulation Research Laboratory and has over 25 years' experience in research for advanced simulation technology. McQuay currently chairs an Avionics Directorate Integrated Product Team, which is defining and implementing a Collaborative Engineering Environment (CEE) for laboratory-wide use and application of virtual prototyping.

DoD Digital photos

Engineers and analysts will use their desktop PCs as acquisition portals into the Joint Synthetic Battlespace. During requirements definition phase, they will be immersed into a synthetic environment — a two- or three-dimensional wargame where the military worth of the proposed concept can be evaluated with realistic scenarios and locales.



"virtual test drive" now, before I invest extensive resources in their concept. How do I put this in terms that all members of my acquisition team can understand? Under Acquisition Reform, as a program manager I only have *insight and not oversight* of my contractor. How do I get insight into the contractor's effort when I have less people and smaller budgets?

Help Is On the Way

Good news – help is on the way. Some innovative uses of simulation and information technologies will bring technical and program management data in a comprehensible format to a personal computer near you: desktop virtual prototyping and collaborative engineering. Changes in simulation and information technology now allow computer engineers to create computer models of conceptual hardware systems prior to building the actual hardware. The collaborative development of a digital computer model in parallel with the hardware is called Collaborative Virtual Prototyping (CVP). Any definition of CVP must encompass all of the following characteristics:

> *CVP is the application of advanced information systems technology in design, modeling, simulation, analysis, manufacturing, testing, and logistics to support life-cycle development of a system in a geographically distributed electronic environment.*

Its use throughout DoD is consistent with current acquisition trends in the Department as well as the commercial sector (Figure 1).

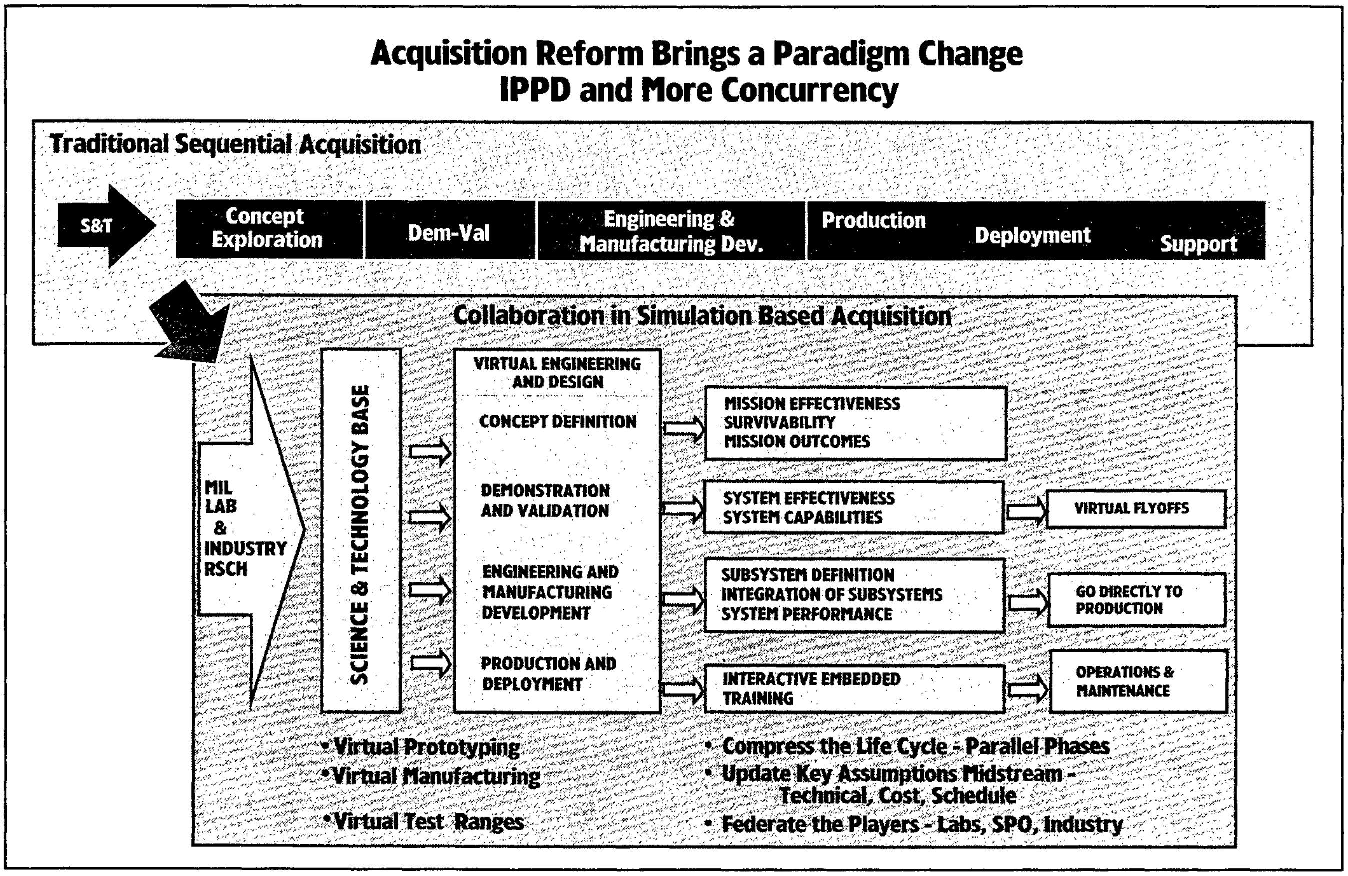
> **"Changes in simulation and information technology now allow computer engineers to create computer models of conceptual hardware systems prior to building the actual hardware."**

Acquisition Reform and the Joint Synthetic Battlespace — Made Personal

DoD has implemented significant changes in how it buys weapon systems. The new emphasis is on concurrent engineering with Integrated Product and Process Development (IPPD) and collaboration with Integrated Product Teams (IPT). The new DoD vision includes Simulation Based Acquisition, a process supported by robust, collaborative use of simulation technology that is integrated across acquisition phases and programs.

To be competitive in their fields, throughout the commercial sector world-class companies in the automotive, electronics, aircraft, and heavy equipment manufacturing areas use CVP and collaborative engineering for requirements, analysis, and design. You, as a program manager, will be working with companies that use these technologies to design their products. As partners in developing DoD products, these companies will be applying the best industry

FIGURE 1. **Simulation Based Acquisition**



practices to your work, and you will need to collaborate with them.

Today, a commercial-sector program manager can turn on a personal computer (PC) on the desktop, check E-mail, and then look at the status of the program, – a completely paperless, electronic review. That same program manager can distribute solicitations electronically, and receive return proposals by the same mode. Along with the standard full text descriptions of the technical task in their return proposals, contractors can also submit a digital model of the concept or design.

The program manager's technical evaluation team can look at an electronic representation of the proposal in the form of a computer model. The model then becomes part of an electronic design and a simulatable specification for the system. Further, the technical team can also "what if" – hypothesize uses of the system and run excursions on competing versions of the same concept or design.

In the commercial sector, a virtual prototype of a car or a plane allows design teams to walk through the virtual prototype to see how the components are changing. The virtual prototype serves as a common frame of reference for the designers, engineers, and managers. It allows you as the program manager, to establish a level playing field for consistent comparisons among alternative concepts and designs. Ideally, CVP provides the insight you need into what your contractor is doing.

Even earlier in the acquisition process, the program or technical manager can work with the user to define requirements using a virtual prototype. Historically, program requirements are difficult to quantify and verbalize. Users are able to state what they don't want much easier than describing what they do want. A simulation model developed in parallel with the hardware or technology development allows scientists, engineers, or end users to refine system requirements early in the engineering process. The users then become an integral part of the design process. Ultimately, when program managers follow IPPD procedures and bring users into the design process, commercial-sector applications show a significant decrease in development time. As we extend this approach to military acquisition, the Air Force Battlelabs will allow the operational commands to do a "virtual test drive" of new weapon concepts and provide feedback to the acquisition community.

Within the Air Force, we envision an integrated, common modeling and simulation (M&S) environment that will be accessed by analysts, warfighters, developers, and testers supporting the range of Air Force tasks, from determining requirements through conducting operations. The key concept in the Air Force M&S vision is the Joint Synthetic Battlespace – an integrated M&S environment where simulations extend from high-level aggregate models to detailed engineering

models, from pilots in live aircraft and simulators to hardware components and laboratory test beds.

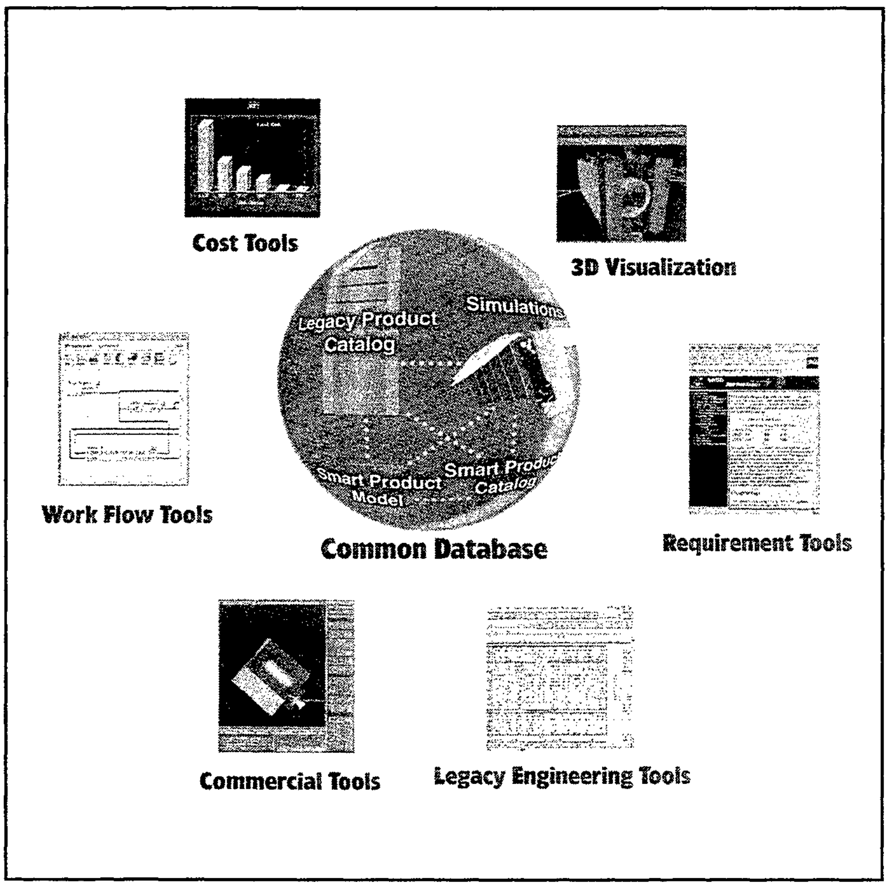
Your desktop PC will be your acquisition portal into the Joint Synthetic Battlespace. During requirements definition phase, you will be immersed into a synthetic environment – a two- or three-dimensional wargame where the military worth of the proposed concept can be evaluated with realistic scenarios and locales. Such a system allows the user to selectively choose the level of detail needed for the task at hand, draw on distant resources, and easily "plug-and-play" computer simulations, manned simulators, and live hardware to create any needed simulation environment. Demonstrations of a future system's military worth will be conducted in the synthetic environment represented by the Joint Battlespace. More than just acquisition – analysts, researchers, decision makers, and warfighters must be able to "plug in" to a common battlespace from their desks, simulators, or crew stations in order to assess, develop, train, or conduct warfighting.

Your industry counterpart has long been driven by cost as the bottom line. Under Acquisition Reform, DoD will make buy decisions on life cycle-cost performance trade studies where cost is an independent variable. The future Air Force Collaborative Engineering Environment (CEE) will have constraint-based analysis tools to aid in early, high-level concept trade studies for cost of function and cost of performance for various alternative technologies.

> ***"Your desktop PC will be your acquisition portal into the Joint Synthetic Battlespace."***

A virtual prototype allows the engineer to see the impact of design changes. Trade studies using the model can then be performed throughout development as an essential part of the systems engineering process.

FIGURE 2. **CEE Built on the DARPA SBD Framework**



A Collaborative Research and Engineering Environment Near You

Two of the most significant, technologically advanced programs are the Avionics CEE development project being conducted at the Avionics Directorate, Wright Laboratory (Figure 2); and the advanced research underway at the Defense Advanced Research Projects Agency (DARPA) Simulation Based Design (SBD) program. The Avionics Directorate has initiated a program to develop and exploit collaborative engineering technologies and implement a CEE to enhance productivity by advancing avionics collaborative virtual prototyping processes. It will build on the significant commercial technology base existing for electronic systems design, DARPA's SBD initiative, and other commercial/industry information and modeling standards and best practices.

Collaborative Engineering and Virtual Prototyping is the application of advanced distributed M&S and engineering tools in an integrated environment to support technology development, system design, performance, cost, and producibility trade-off analyses throughout the entire product and system engineering life cycle. As such, it enables all members of an IPPD to continuously interact through electronic modeling and data interchange; increases insight into life-cycle concerns; permits earlier testing and

experimentation through virtual test ranges; and accelerates physical production through process optimization using virtual factories.

Additionally, Collaborative Engineering simulations, with integral product and process models, will permit engineers to obtain detailed knowledge earlier in the conceptual and preliminary design phases where it can have the most influence on life-cycle cost. More emphasis will be placed on the collaborative development of virtual prototypes of key technology products to demonstrate their military effectiveness and worth in an *integrated systems/mission environment.*

As downsizing trends continue in both defense and industry, the military and commercial laboratories will increasingly depend on other organizations for key technologies to integrate into systems. Additionally, increasing demands will be placed on technology to facilitate more efficient, effective collaboration of widely dispersed personnel across many different application domains in order to solve complex problems and accomplish difficult tasks.

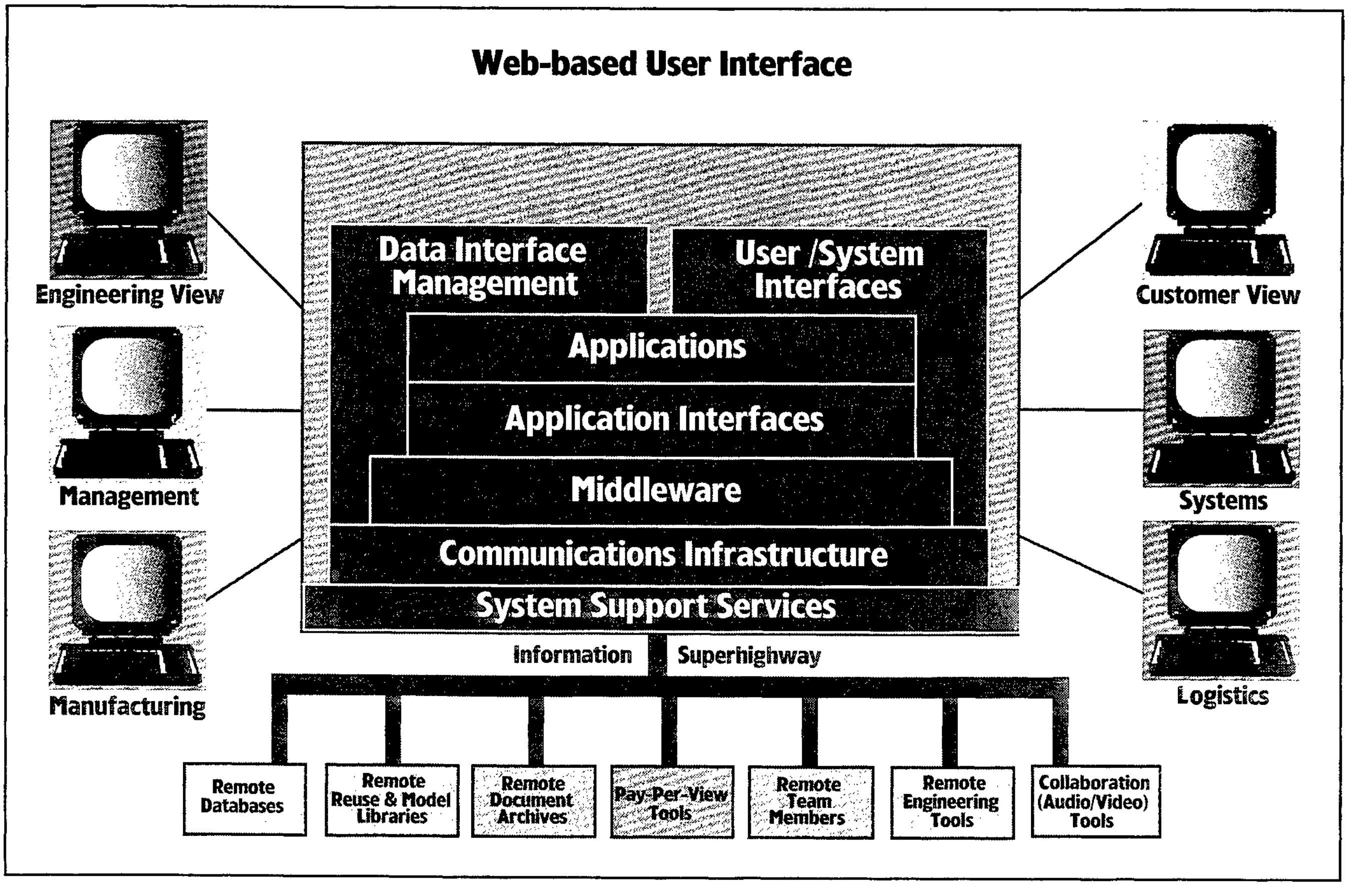
As an initial response, CVP meets the demand for technical assistance and provides the infrastructure to support these new acquisition requirements. It will also assist in the breakdown of technology stovepipes and become the construct for communication of technologies between domains.

CVP can be implemented in many organizational structures. Traditional hierarchical workplaces, concurrent engineering environments, and work groups focused on rapid prototyping are a few examples. Implementation of a CVP system requires attention to the necessary enabling technologies and supporting infrastructure. A crucial part of a CVP system implementation is educating personnel on how CVP can meet customer, organizational, and individual goals as well as decrease time-to-market, lower life-cycle costs, and improve product quality.

Historically, 80 percent of the development costs and 70 percent of a product's life-cycle cost are determined during conceptual design. As the program moves from conceptual design into engineering and manufacturing development, the ability to substantially influence life-cycle costs diminishes. The freedom to make design changes decreases as the knowledge about the system design increases. In other words, a progression from soft to hard information occurs as the system moves from the conceptual phase to the detailed design phase.

CVP can move the knowledge curve to the left and increase the hard information available in the early stages of design. This improvement in the quality of information should benefit the acceleration of the technology maturation and ultimately facilitate

FIGURE 3. **Multiple Views in Collaboration**



technology transition. The end result should be designs completed in less time and at less cost.

The use of M&S in the design, development, and distribution of products is not a new concept or idea. The DoD and industry have been using virtual prototyping within many of their individual functional departments and organizations for many years. However, these individual *stovepipe* groups of functionality have not interacted with each other in an effective way and have oftentimes duplicated functionality.

A CVP system provides the capability to integrate *stovepipe resources* and increase the collaborative interactions of the people using the resources. Thus, the old mindset of having to move resources needed to do a particular job local to one location is no longer necessary or valid.

In the future, clusters of geographically separated resources will be integrated by advanced communications networks into a virtual system. Users will search repositories for the resources needed to solve their particular application, will assemble and configure the resources into a virtual system, and will execute or use the virtual system to solve their problem or accomplish their task. Additionally, products resulting from one task will seamlessly interact with the products of other tasks to accomplish unique functions.

The Collaborative Research and Engineering Environment will emphasize *product and process* models. Product and process model applications capture and provide information about a product technology development process.

Product Models. These models provide details about the specifications and requirements of a product, its structure and behavioral characteristics, its design and development constraint rules, and the different versions of the design and implementation. In this context, a product can be a prototype piece of hardware, a report, or an experiment/session. Product models also define any special test equipment or facilities required to support design and/or development. For CVP, the product models will have a virtual prototype as the central focus of all other information gathered and collected.

> ***"Collaborative Engineering simulations, with integral product and process models, will permit detailed knowledge to be obtained earlier in the conceptual and preliminary design phases where it can have the most influence on life-cycle cost."***

Process Models. While product models focus on all aspects of the product design and development, process models provide detailed definitions of the engineering, development, and evaluation processes used to design and develop the product. Specifically, process models provide information and knowledge on how to use various tools and resources to perform the numerous scientific, engineering, development, and evaluation tasks associated with technology and product development.

Making Collaboration Work for Each Team Member

Each IPT is made of many participants with different backgrounds, experiences, and specialties. They literally do not speak the same language. The Collaborative Research and Engineering Environment must provide a domain-specific view in the native terminology of each of your team participants. There will be multiple user interfaces as shown in Figure 3. For example, the engineers on the IPT must be able to employ the applications that they customarily use. The engineering user interface must be intuitive for the engineering domain. Similarly, the manufacturing, financial, logistics, management, and end user must be able to access the information, databases, and virtual prototypes in a fashion natural to their way of doing business.

The overall architecture for the CEE is a layered, open-systems approach. The infrastructure consists of that hardware and software which provides functionality to the user, but resides in the background and does not directly interact with the user. The user sees a consistent interface that is based on Web technologies that provide portability to many different platforms, including the workhorse PC on your desktop.

CEE/CVP — Crucial Ingredients

Advances in software and computer technology are making desktop CVP possible and affordable for the engineering process in government and industry research. CVP will become a crucial means of sharing technology and systems integration for research and development and is a natural extension of the Air Force vision for an integrated, common M&S environment, accessed by analysts, researchers, warfighters, developers, and testers. Virtual prototyping and a CEE are crucial ingredients for Acquisition Reform – providing insight for the program manager.

The Theater Missile Defense System Exerciser

TMDSE — Build a Little, Test a Little

LT. COL. STEVE MCQUEEN, U.S. AIR FORCE
RAYMOND B. WASHBURN, P.E. • JOHN F. MORASH

Theater ballistic missiles and cruise missiles are a major threat to U.S. forces deployed almost anywhere in the world. To counter this threat, an extremely sophisticated family of theater missile defense (TMD) weapon systems has been developed. To achieve the maximum firepower effectiveness, however, today's TMD Family of Systems (FoS) must be highly interoperable to counter a broad spectrum of threats, environments, and deployment scenarios.

The Theater Missile Defense System Exerciser, or TMDSE, offers the only hardware-in-the-loop (HWIL) test capability available to integrate the entire TMD FoS and test interoperability issues that exist between the separately developed TMD systems.

The TMDSE is a computer-based test tool used to verify interoperability between geographically distributed TMD systems and sensors. This tool "drives" tactical TMD weapon systems with a time-synchronized simulated environment, including threats (theater ballistic missiles, cruise missiles, and aircraft), weather, and terrain.

In June of 1994, the U.S. Army Program Executive Office for Air and Missile Defense (PEO AMD) located in Huntsville, Ala., successfully conducted a Proof-of-Principle (POP) demonstration of a test tool concept that would later become the TMDSE. This POP demonstration, that validated the concept, illustrated the interconnection of two remote TMD tactical hardware sites (the U.S. Army PATRIOT Flight Mission Simulator [FMS] in Bedford, Mass.; and the U.S. Army Joint Tactical Ground Station [JTAGS] located in Azusa, Calif.), simultaneously driven in real time with a common theater test environment.

Following the TMDSE POP, the Ballistic Missile Defense Organization (BMDO) then directed that PEO AMD in Huntsville, Ala., develop the TMDSE, thereby providing the capability to verify that the TMD FoS are integrated and can effectively interoperate across the spectrum of threats, environments, deployments, and contingencies that are delineated in their respective operational requirements documents.

Under the direction of the Deputy for Acquisition/Theater Missile Defense, BMDO, TMDSE development is in its third year and proceeding to an enhanced Build 2 capability. Air Force Lt. Col. Steve McQueen, BMDO/AQI, Systems Integration/BMC3, is the Program Integrator. As executing agent for BMDO, PEO AMD is responsible for the development of the TMDSE Control Segment, development of the Army "drivers," and integration of all Joint elements.

The TMD systems that are integrated into TMDSE will be combinations of existing inventory, product upgrades, and new systems that evolve to enhance mission effectiveness. Its phased, incremental development approach also allows TMDSE to be systematically upgraded to higher levels of fidelity and complexity to support the evolving TMD architecture and its resulting test needs.

As the complexity of the deployable TMD Systems and their operating environments increases, so must the capability of the TMDSE. The implementation of BMDO's direction will be accomplished through the phased development of the TMDSE. Each phase during this development progression is referred to as a Build.

TMDSE Build 1 Configuration

TMDSE's developers, Nichols Research Corporation and Teledyne Brown Engineering, of Huntsville, Ala., completed the TMDSE Build 1 config-

McQueen is the Program Integrator for the Theater Missile Defense System Exerciser (TMDSE) Program. He currently works for the Ballistic Missile Defense Organization, Acquisition System Integration /BMC3 Division (BMDO/AQI), in Washington, D.C. McQueen is a graduate of PMC 94-1, DSMC.
Washburn is a professional engineer with the Program Executive Office for Air and Missile Defense in Huntsville, Ala., and a member of the Army Acquisition Corps (AAC). He is also the executing agent and program manager for the Army portion of the TMDSE Program. Washburn has almost 10 years of prior simulation experience, including work as program manager on the following simulations: Extended Air Defense Simulation, Israeli Testbed, and the United Kingdom Testbed.
Morash is a software engineer with the Program Executive Office for Air and Missile Defense in Huntsville, Ala., and a member of the Corps Eligible program of the AAC. He is also the Assistant Program Manager of the Army portion of the TMDSE Program. Morash has six years of prior simulation experience, including three years on the Extended Air Defense Testbed.

U.S. Army digitized photos/illustrations

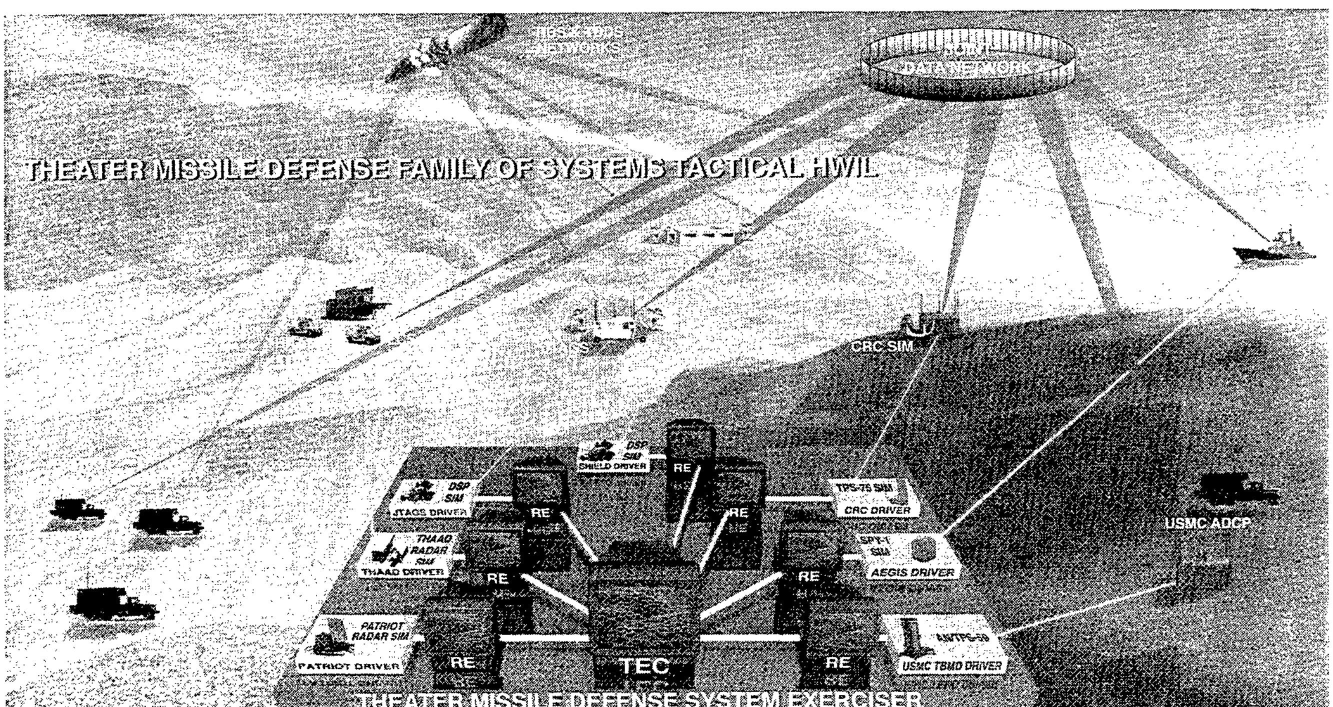
uration in April 1996. Upon completion, the TMDSE Build 1 had 200,000 lines of Ada code. The TMDSE Builds, leveraging heavily from the various Major Defense Acquisition Programs and other defense systems that make up the TMD FoS, make TMDSE a very cost-effective HWIL test capability. As configured, TMDSE interfaces directly with each weapon system via its existing tactical driver, and does not require co-location of test articles. Five sites jointly participated in the TMDSE Build 1 configuration:

- U.S. Army PATRIOT Engagement Control Station (ECS) and Information Control Center (ICC) at the U.S. Army's Missile Command (MICOM) Software Engineering Directorate, Huntsville, Ala.
- U.S. Navy AEGIS Weapon System at the Naval Surface Warfare Center (NSWC) AEGIS Computer Center (ACC) at Dahlgren, Va.
- U.S. Army Joint Tactical Ground Station (JTAGS),PEO AMD, Huntsville, Ala. (The actual JTAGS shelter driver was and is housed at Aerojet Corporation in Azusa, Calif.)

The TMDSE is a computer-based test tool used to verify interoperability between geographically distributed TMD systems and sensors. TMD systems and sensors. This tool "drives" tactical TMD weapon systems with a time-synchronized simulated environment, including threats (theater ballistic missiles, cruise missiles, and aircraft), weather, and terrain.

- U.S. Air Force SHIELD at the Joint National Test Facility (JNTF), Falcon Air Force Base, Colorado Springs, Colo.
- U.S. Air Force Control and Reporting Center (CRC) at the Theater Air Command and Control Simulation Facility (TACCSF), Kirtland Air Force Base, Albuquerque, N.M.

One of the things that separates the TMDSE from other simulations and contributes to its uniqueness is its use of real tactical hardware and real tactical communications. During actual TMDSE execution, the TMDSE makes use of a real PATRIOT ICC and real PATRIOT TMDSE Control Segment shelters, real AEGIS weapon system computers and software, real JTAGS computers and software, and real satellite broadcasts. (The simulated threat "injected" into the JTAGS and SHIELD systems will generate real Tactical Information Broadcast Service [TIBS] and TRAP Data Distribution System [TDDS] cueing messages that will be received by the PATRIOT, AEGIS Weapon System, and CRC elements.)



The Theater Missile Defense System Exerciser or TMDSE offers the only tactical Hardware-in-the-Loop (HWIL) test capability available to integrate the entire Theater Missile Defense Family of Systems (TMD FoS) and test interoperability issues that exist between the separately developed TMD systems.

The TMDSE system is connected to its remote sites using two separate networks: one that addresses the test control functionality of the system, and the other that provides the tactical communications network for the systems under test. These communication networks consist of a combination of local and wide area networks, high bandwidth (i.e., T1 1.544 megabit per second) telephone lines, KG-194 encryption devices, and secure telephones (STU-IIIs), which connect the TBE Test Exercise Controller (TEC) hub to the geographically distributed TMD Tactical Drivers.

The first of these is the TMDSE test control network, which is comprised of high band width (T1) encrypted telephone lines that join the TEC with all Remote Environments at each Tactical Driver site. This network provides a common, synchronized environment to the various tactical systems via a common standardized set of Distributed Interactive Simulation (DIS) protocol data units (PDU). Using DIS PDUs, TMDSE injects a real-time, common threat scenario into real, geographically distributed tactical sensors and weapon systems. The tactical systems respond in real time via their respective tactical communication data nets, including TIBS/TDDS and the Joint Data Net, allowing each individual TMD system to operate synergistically in a tactically realistic battlefield.

This test control network allows the TMDSE to –

- generate realistic scenarios, including natural (weather and terrain) and artificial environments, including tactical missiles and air-breathing threats;
- generate realistic missile interceptor flyouts;
- generate realistic interceptor and threat debris in real time;
- coordinate and synchronize the stimulation of the track processing systems; and
- coordinate and synchronize dynamic events that are a result of offensive/defensive actions. ("Dynamic" events, as opposed to "scripted" events such as tactical missile flyouts, are the defensive actions taken by the tested weapon systems in response to the scripted threats. For example, the reaction(s) of a PATRIOT fire unit to approaching tactical missiles or aircraft must be represented dynamically in real time.)

The second network used, the tactical communications network, connects the tactical systems to each other. These interfaces must appear to be the natural communications expected of the TMD components with regard to protocol, message formatting, and routing selection. Actual Joint Tactical Information Distribution System (JTIDS) radio terminals cost approximately $1 million each and operate via line-of-sight, which means that they are restricted to distances of 30-50 kilometers. Due to the high cost of these radios and the fact that geographically distributed TMDSE systems are sometimes separated by distances of hundreds or thousands of miles, another means had to be found to emulate tactical communications.

For TMDSE, the U.S. Naval Command, Control, and Ocean Surveillance Center's Link 16 Emulator and Communications Monitor (the "NRaD Gateway") provided the tactical communication link connectivity between the individual weapon system platforms using the Tactical Digital Information Link (TADIL) J protocols and message formats emulating a JTIDS. Future planned enhancements to the NRaD Gateway will increase the fidelity of the TMDSE and allow land-line emulation of satellite transmissions.

In the first quarter of fiscal year 1997, the TMDSE Build 1 configuration was installed at the Joint National Test Facility (JNTF) located at Falcon Air Force Base in Colorado Springs, Colo. BMDO designated the JNTF to be the operational facility where FoS tests will be run. PEO AMD, however, will continue as the developer for the follow-on configurations.

TMDSE Build 2 Configuration

The TMDSE Build 2 is scheduled to be completed by July 1997. By the end of third quarter, fiscal year 1997, the TMDSE Build 2 requirements and functional capabilities will demonstrate an evolving capability for TMD system integration and interoperability testing. In addition to the original five TMDSE Build 1 systems (PATRIOT, AEGIS, CRC, JTAGS, and SHIELD), the following two additional TMD Tactical Systems will participate in the Build 2 configuration:

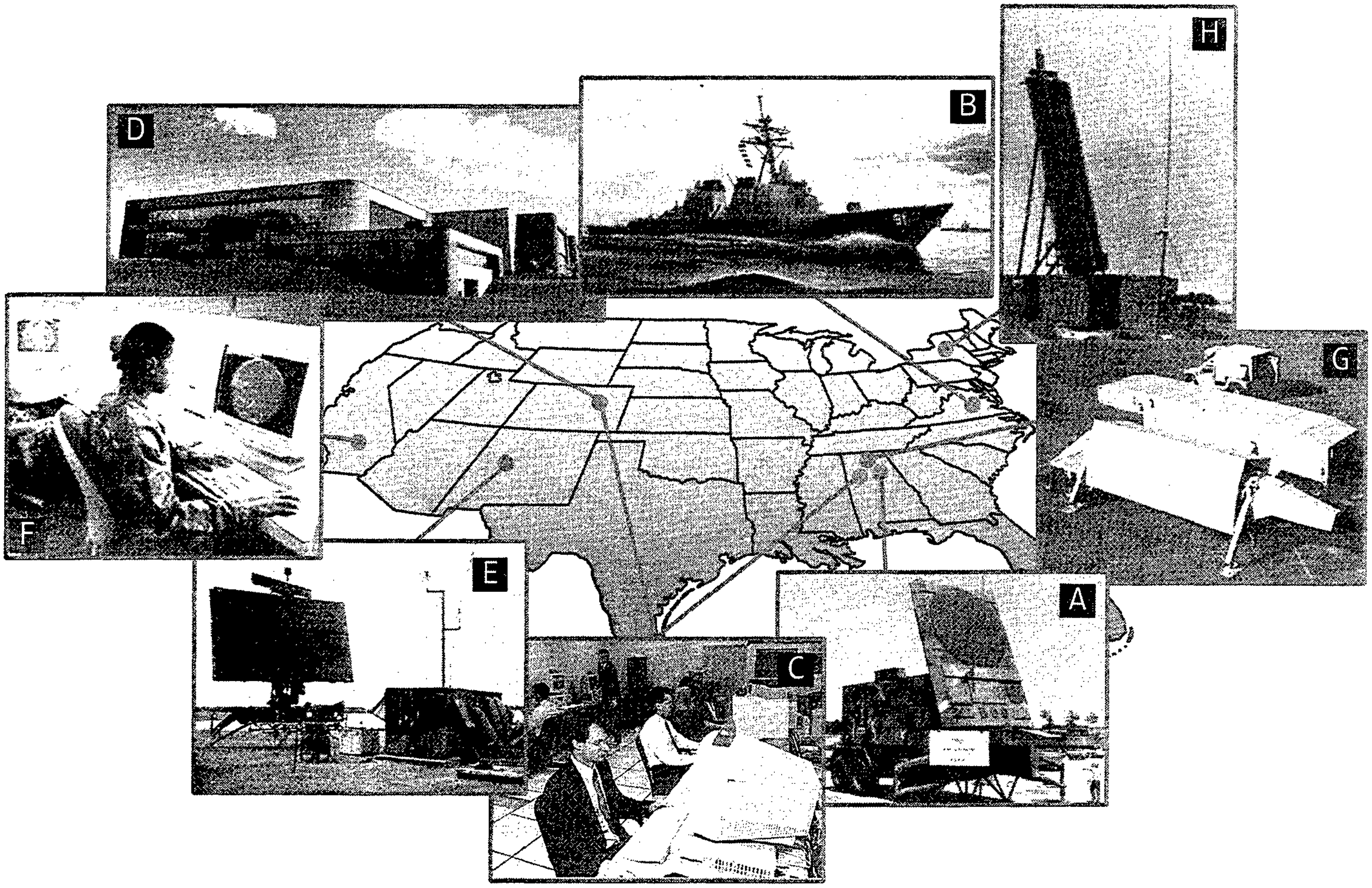
- U.S. Army Theater High Altitude Area Defense (THAAD) weapon system, PEO AMD, Huntsville, Ala.
- U.S. Marine Corps HAWK TPS-59 radar system, USMC Systems Command, Syracuse, N.Y.

TMDSE Verification, Validation, and Accreditation (VV&A)

The technical difficulties and costs associated with ensuring adequate verification and validation (V&V) of modeling and simulation (M&S) are major challenges in successfully executing a simulation development enterprise within the DoD. In today's current regulatory environment, DoD and Service policies and directives generally mandate that M&S be subjected to a formal, structured verification, validation, and accreditation (VV&A) program. Within the Services, and BMDO in particular, guidance and oversight for M&S VV&A is becoming quite explicit. Timely and successful accreditation of simulations with embedded legacy models and codes, such as TMDSE, require explicit, focused V&V evaluations that are tied to the simulations' intended use.

The best means for accomplishment of this complex task is a rigorous, focused V&V and evaluation effort, which is adaptable to the particular unit-under-test. Currently, for TMDSE a tailored V&V program is being pursued that is based on –

- leveraging ongoing, system-level simulation development, test, and V&V activities;



The TMDSE Build 1 configuration consisted of joint participation by the following five sites: (A) U.S. Army PATRIOT Engagement Control Station (ECS) and Information Control Center (ICC) at the U.S. Army's Missile Command (MICOM) Software Engineering Directorate (SED), Huntsville, Ala.; (B) U.S. Navy AEGIS Weapon System at the Naval Surface Warfare Center (NSWC) AEGIS Computer Center (ACC) at Dahlgren, Va.; (C) U.S. Army Joint Tactical Ground Station (JTAGS), PEO AMD, Huntsville, Ala. [(F) the actual JTAGS shelter driver was and is housed at Aerojet Corporation in Azusa, California]; (D) U.S. Air Force SHIELD at the Joint National Test Facility (JNTF), Falcon Air Force Base, Colorado Springs, Colo.; and (E) U.S. Air Force Control and Reporting Center (CRC) at the Theater Air Command and Control Simulation Facility (TACCSF), Kirtland Air Force Base, Albuquerque, N.M. In addition to the original five, TMDSE Build 1 systems (PATRIOT, AEGIS, CRC, JTAGS, and SHIELD), two additional TMD Tactical Systems will participate in the Build 2 configuration: (G) U.S. Army Theater High Altitude Area Defense (THAAD) weapon system, PEO AMD, Huntsville, Ala.; and (H) U.S. Marine Corps HAWK TPS-59 radar system, USMC Systems Command, Syracuse, N.Y.

- verifying TMDSE through a series of well-defined and coordinated functional configuration audit activities;
- validating TMDSE at the system level by explicitly linking TMDSE validation activities to existing, ongoing, or planned system test activities as the principal source of "real world" data; and
- generating the essential information necessary for V&V reports and findings, which provide the evidence required to support the accreditation decision by potential TMDSE users and operational testers.

The set of specific validation activities selected for execution are being closely coordinated with the individual system developers and will be based upon TMDSE accreditation data needs, the realities of the system programs, and the fixed resources available for TMDSE V&V within the respective Services and BMDO. The validation activities for TMDSE are being defined by the sponsor for execution by the respective system simulation activity.

Hardware-in-the-Loop Test (HWILT)

The fiscal year 1996 BMDO Hardware-in-the-Loop Test (HWILT-96) was conducted in September 1996 using the TMDSE Build 1 software. Navy Cmdr. Don Gold of BMDO was the program integrator for the HWILT-96. The test was executed and controlled under the direction of Army Lt. Col. Chuck Treece of PEO AMD, from the develop-

mental TMDSE Test Exercise Controller located at Teledyne Brown Engineering in Huntsville, Ala.

The HWILT-96 tactical weapon system participants generated and distributed tactical communication messages, including Joint Data Network, TADIL-J, and live TIBS and TDDS broadcasts. Dedicated TIBS and TDDS exercise channels were used by TMDSE during the test to preclude the broadcast of exercise tactical event messages into the actual scenario theater's operational network. Ongoing analysis of the collected data is currently being conducted.

For the HWILT-96, a northeast Asia scenario, including a dynamic environment of threats (theater ballistic missiles, aircraft, and cruise missiles), interceptors, weather, terrain, and threat/interceptor fragment debris was injected into the HWIL tactical weapon systems. The HWILT-96 test event employed real tactical TMD assets and operators, communicating via real-world tactical communication links responding in real time as if in an actual battlefield situation.

Future HWILTs will be executed and controlled from the BMDO JNTF, Falcon Air Force Base, Colorado Springs, Colo. Installation of the TMDSE Build 1 capability has been completed at the facility. Upon completion and demonstration, subsequent TMDSE builds will be installed at the JNTF for the operational execution of future TMD FoS tests.

The successful execution of the HWILT-96 enabled the establishment of policies and procedures for direction and conduct of future FoS tests, the development of lessons learned from the early use of TMDSE for FoS testing to support definition of future TMDSE enhancements, and early insight into FoS interoperability with respect to selected TMD Command and Control (C^2) Plan objectives. This experience, in conjunction with the full cooperation between BMDO, the operational test agencies, and the Services will make TMDSE the tool of choice whenever TMD system test and evaluation issues are addressed.

Leveraged Activities

The PEO-AMD provided critical support to Joint Project Optic Cobra (JPOC) '96 and Joint Exercise Roving Sands '96, conducted in June 1996. JPOC is an annual U.S. Central Command TMD exercise supported with BMDO funding. Conducted in the Fort Bliss, Texas, and White Sands Missile Range, N.M., areas as a part of the U.S. Forces Command-managed Joint Exercise Roving Sands, JPOC is the world's largest Joint Tactical Air Operations exercise. During the exercise, PEO AMD successfully implemented and executed the Cooperative Air and Missile Defense Network (CAMDEN), a distributed interactive simulation infrastructure capability that provides an integrated tactical missile and aircraft training environment for the U.S. and allied soldiers, sailors, airmen, and Marines participating in the Roving Sands exercise. Some CAMDEN components were derived from ongoing PEO AMD simulation and test and evaluation programs funded by BMDO, the Defense Modeling and Simulation Office, and from other Service and Joint programs. Particularly noteworthy, however, are the TMDSE-developed elements that include the PATRIOT Digital Flight Mission Simulator, the JTAGS simulator, the THAAD Test Controller, and the AEGIS weapon system at NSWC.

Summary

With declining resources, missile flight test costs are a major expense to program offices. Many constraints influence live flight tests such as range restrictions, treaty limitations, environmental concerns, and range safety issues. Program offices are no longer able to conduct the number of flight tests that they once did. A single flight test can cost from $25 to $50 million when target, interceptor, range, and personnel costs are figured in. In addition, the number of simultaneous engagements per test is limited to probably no more than two. However, weapon system interoperability assessment is required in a "target enriched" environment. For these reasons, HWIL testing is becoming increasingly important due to the significant cost savings that can be achieved by its use, and the TMDSE is being viewed as BMDO's key FoS test tool resource.

TMDSE is more economical than live flight tests and allows TMD systems to explore interoperability issues into areas not possible during live flight tests, such as multiple, simultaneous engagements and stressing environments. Expanding beyond range limitations as well as logistical considerations, TMDSE provides an economic solution to live flight tests.

The TMDSE is an integral part of BMDO's overall test and evaluation strategy that supports the successful acquisition of the TMD FoS. The strengths of the TMDSE include its design flexibility that facilitates the incorporation of new tactical weapon system elements by easily interfacing these elements into the distributed, real-time TMDSE network. As the TMD FoS evolves, the TMDSE will mature to meet the challenge of assessing the interoperability of these deployed weapon systems.

The "build-a-little, test-a-little" methodology implemented for the TMDSE will reduce development risks, pace the program to the funding appropriations, and tailor the "builds" to the TMD weapon system development schedules. The experience of the PEO AMD TMDSE development team has provided a solid foundation to leverage into the Build 3 development effort. This experience, in conjunction with the full cooperation between BMDO and the Services, will make TMDSE the tool of choice whenever TMD system test and evaluation issues are addressed.

For additional information on the TMDSE Program, visit **http://peoamd.redstone.army.mil/tmdse/** – our TMDSE Home Page on the World Wide Web.

A New Vision, Further Leveraging Emerge From Orlando's Simulation Superstructure

WTET Prototype Developed By Collaboration, Partnerships, Cooperation Between Government and Industry

JEFFREY D. HOREY

"Defense capabilities in education and training represent an important resource. New programs will accelerate transfer of this experience to civilian institutions. The Department of Defense and NASA [National Aeronautics and Space Administration} have invested heavily, both in the hardware and software needed for advanced instructional systems; they have accumulated valuable experience in how to use the new technologies in practical teaching situations. The Navy Training Systems Center [now the Naval Air Warfare Center Training Systems Division] and the Army Simulation, Training, and Instrumentation Command together spend about $1 billion a year on training systems. There are over 150 defense simulation and training companies serving these needs in Central Florida alone...."[1]

—President William J. Clinton
Vice President Albert Gore, Jr.
February 22, 1993

From the nationally recognized simulation superstructure in Orlando comes a new vision – and further leveraging.

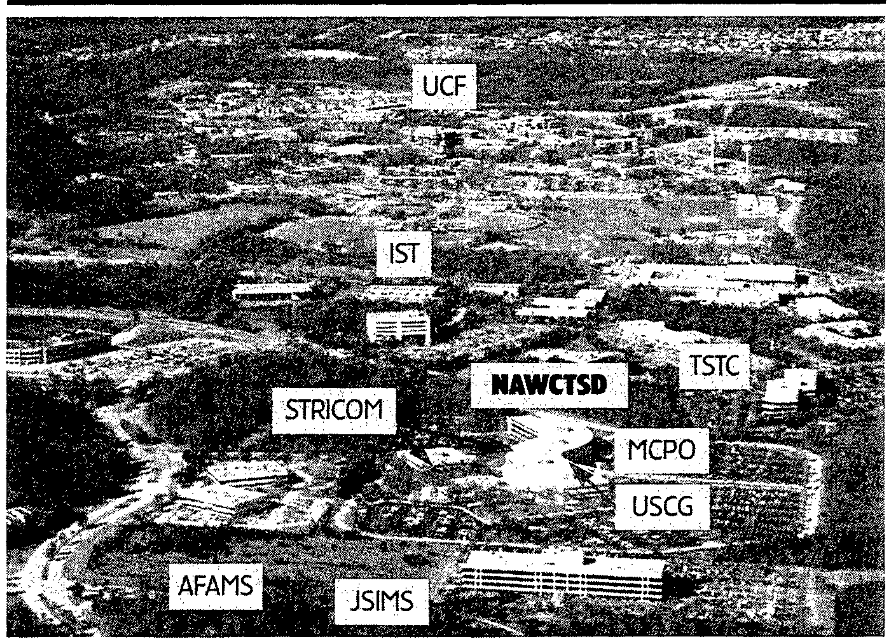
The acquisition manager of today must be aware of alternative vehicles, available outside of the Federal Acquisition Regulations, which can be used to ensure a technologically superior product, produced in a cost-effective manner by a reliable industrial source.

Weapons Team Engagement Trainer

An example of one such vehicle is the cooperative agreement among the Naval Air Warfare Center Training Systems Division (NAWCTSD); SBS Technologies, Inc.; and Camber Corporation, to produce the Weapons Team Engagement Trainer (WTET). The Office of the Secretary of Defense, under the Defense Laboratory Partnership Program for Technology Transfer, funds the agreement.

The WTET is an advanced Special Weapons and Tactics (SWAT) training system that allows multiple member weapon teams to participate in multiple room (and multiple screen) threat engagements, under shootback and advanced individual and team performance feedback conditions. NAWCTSD initially developed the system.

FLORIDA CENTER OF EXCELLENCE FOR SIMULATION



Horey is currently a Project Director, Naval Air Warfare Center Training Systems Division (NAWCTSD), Orlando, Fla. He holds an M.S. in Industrial Psychology from The George Washington University. For the past 10 years, he has worked in the areas of training assessment, design, and evaluation for NAWCTSD.

A prototype of the WTET was extensively and successfully demonstrated to law enforcement agencies and special operations groups of the U.S. military. The enhanced production version will be demonstrated in 1997. It will provide instructor-controlled training and feedback for a wide range of law enforcement and military threat situations. Included in the system will be the training capability for use of force decision making; marksmanship skills and analysis; SWAT operations, including sniper training; and use of less-than-lethal-force weapons.

Industry and the Commercialization Process

The industry partner, SBS Technologies, Inc., already produces a judgmental use-of-force trainer, for both the law enforcement and military communities. Under the commercialization of WTET, the merging of their current trainer and the many unique features of WTET will result in a training system that will provide a full and complete range of weapons, team, and engagement training under realistic tactical situations.

This is the first use of a cooperative agreement for commercialization within the Naval Air Systems Command, NAWCTSD's parent organization. As such, WTET has been designated as a pilot project.

Authority to use the legal vehicle selected for this commercialization process – the cooperative agreement – was recently granted to the military services.

The commercialization process consists of a two-year cycle of system development by NAWCTSD and its industry partners, along with the direct involvement of the user community. Traditional programmatic reviews are ensured during the life of this nontraditional technology transfer project. The program management, engineering oversight, and training requirement functions during the commercialization are being performed by NAWCTSD.

User Community

Interested user agencies also will be integrated into the effort to ensure the final product reflects the requirements of the military and civilian law enforcement communities (federal, state, and local). As part of the program plan, two systems will be available for evaluation by those communities.

Sponsored in part by the National Institute of Justice, the initial system installation has been designated for the Los Angeles County Sheriff's Department Laser Village Training Facility. Ideally, it should be operational by the end of 1997, and will be available for use by military and law enforcement agencies in and around Los Angeles.

Commenting on the system, Lt. Mike Grossman, manager of the Force Training/Laser Village Training Facility in Los Angeles, says, "It doesn't get any better. It's really a great opportunity to be able to participate in a program where so many different agencies are working to make this happen, and be able to provide state-of-the-art training for Southern California – for military, federal, state, and local law enforcement. I think the sharing of knowledge and expertise, and the joint venture doesn't get any better. We appreciate the opportunity to be the host for this kind of operation."

A second system will be available for demonstration at relevant trade shows and for possible temporary installations at select user agencies.

Product Concept Evolves

Cost reduction is not the only advantage of this dual-use effort. Since the cooperative agreement between the Navy and its industry partner was signed in February, 1996, the concept of the product has evolved.

The concept for the commercially produced system now incorporates marksmanship, use-of-force decision making, special weapons and tactics, and advanced military weapon team training into a user-friendly, easily upgraded modular system design.[2]

Other Opportunities

Other opportunities exist for collaboration between the Department of Defense and the entertainment industry. Mechanisms are available that encourage the government's collaboration with industry to conduct joint research and development (R&D). Under this framework, the government gains the right to use the research results for government purposes; the company holds all commercial rights. Both partners share the costs of conducting the research.

Products such as games and location-based entertainment, as well as the underlying technology used to create entertainment products are targets of opportunity.

Why would the Navy consider partners with such widely diverse motivations and objectives? Both actively draw from modeling and simulation technologies, to produce products.

The Navy uses commercial games in training programs, on a limited basis. The games are used as a "backdrop" to stimulate behavior – such as coordination and communication between pilots and crew.

Consider the sailor or student of today. Many have hands-on experience – and expertise – with PC-based learning. The Navy has found that computer-based games provide an effective, low-cost way to simulate flying and other task experiences. The applications must be appropriate – those that do not require expensive hardware/software to create highly accurate, real-time situations.

The joint R&D does not have to result in a product. It can be directed at the underlying technology. The agreements that promote this collaboration are not covered by the Federal Acquisition Regulations, which apply to government contracts. They can also be exempted from the Freedom of Infor-

mation Act. To attract these commercial partners, the government recognizes that intellectual property must be protected.

Market Dynamics

These types of agreements help move the technology out of the laboratory and into the marketplace. The technology becomes available to civilian users, allowing the military to buy resultant commercial off-the-shelf products.

Invaluable benefits from these market dynamics emerge, as a broader customer base lowers the per-unit cost. The military is getting the commercial price to acquire a system, not "cost-plus." Civilian users gain the benefits of more advanced technology (typically, in the area of learning technology, where the Department of Defense has the lead). We will see more of this technology moving into workforce development and K-12 education.

The rapid pace of change to Department of Defense acquisition policy means that an activity's internal acquisition policy and procedure directives require continuous updating. As a result, NAWCTSD developed the *NAWCTSD Acquisition Guide*, an electronic acquisition guide, considered to be a faster method of communicating new policy to NAWCTSD's own acquisition managers.[3] First introduced in March via the NAWCTSD Website, the guide includes an Acquisition Roadmap, which is a tailored representation of the Department of Defense acquisition process, as revised.

ENDNOTES

1. Clinton, President William J., and Vice President Albert Gore, Jr., "Technology for America's Economic Growth, A New Direction to Building Economic Strength" (The White House, Feb. 22, 1993, p. 14).
2. For more on WTET, visit **http://www.ntsc.navy.mil/wtet/wtet.htm** at NAWCTSD's Website.
3. To view or access the *NAWCTSD Acquisition Guide*, visit **http://www.ntsc.navy.mil/acqguide/acqguide.htm** at NAWCTSD's Website.

COST ANALYSIS STRATEGY ASSESSMENT MODEL (CASA) COMES OF AGE

Lt. Col. Carl Gardner, U.S. Army

The CASA model, profiled in the January-February 1996 edition of *Program Manager* magazine,[1] recently underwent a major overhaul. CASA is actually a set of analysis tools formulated into one functioning unit. It collects, manipulates, and presents as much of the cost of ownership as the user desires. As depicted in the table, CASA's configuration includes a number of programs and models that allow you to generate data files, perform Life Cycle Costing (LCC), sensitivity analysis, LCC risk analysis, LCC comparisons, and summations.[2]

Version 4.0 brings the ease of Windows™ to its users and allows export of data in spreadsheet format. The new logical input sequence (in work breakdown structure format) allows easy data entry. The flexibility to perform "What if" drills is increased by the addition of the capability to vary the levels of maintenance (1-10) and a readiness target. An online tutorial provides initial training and assistance during use. CASA can be downloaded from the following website, via the Defense Systems Management College's Home Page:

http://dsmc.dsm.mil/specfeat/htm

According to Keith McLendon, U.S. Army Logistics Support Activity, CASA Version 4.0 information may also be downloaded from the following website, via the U.S. Army Logistics Support Activity's Home Page:

http://www.logpars.army.mil/CASA.htm

REFERENCES

1. Manary Joel M., "DSMC's CASA Model Still Going Strong," *Program Manager* Magazine, January-February 1996.
2. *CASA Users Manual*, Defense Systems Management College, February 1994.

Editor's Note: Gardner is a Professor of Logistics Management, Logistics Management Department, Faculty Division, DSMC. He is a graduate of APMC 95-1.

CASA CAPABILITIES

Life Cycle Cost Estimating	Trade-Off Analyses	Repair-Level Analyses	Production Rate and Quantity Analyses
Warranty Analyses	Spares Provisioning	Resource Projections (e.g., Manpower, Support Equipment)	Risk and Uncertainty Analyses
Cost Driver Sensitivity Analysis	Reliability Growth Analyses	Operational Availability	Analyses with Automated Sensitivity Analysis
Spares Optimization To Achieve Readiness Requirements	Operation and Support Costs	Contribution by Individual Components of The System	

National Simulation Superstructure

Disney Doesn't Have a Monopoly on the World of "Make Believe"

KATHLEEN M. CLAYTON

The imagination, creativity, and technically sophisticated world of "make believe" for which this city is famous does not begin and end with the creations of Walt Disney. The Department of Defense (DoD) is the fortunate beneficiary of a concentration of modeling and simulation (M&S) expertise – a national simulation superstructure, also located in Orlando. This collection of collocated defense agencies, proven M&S companies, academic institutions with M&S curriculum, and state and local governments is committed to the enhancement and use of this leveraging tool as a vital national resource.

The *Team Orlando* Charter outlines the synergy of the group as they recommit themselves to "work together to share information and leverage programs and technology in the best interest of the Department of Defense and the American taxpayer."

Recognizing the advantages in leveraging this array of talent to provide the best possible products to the Army, the U.S. Army Simulation, Training, and Instrumentation Command (STRICOM) recently led the formalization of the concepts inherent in the success of this unique M&S community. Naming this simulation superstructure *Team Orlando*, STRICOM and six other key players (the Naval Air Warfare Center Training Systems Division [NAWCTSD], the Joint Simulation Systems Office [JSIMS], the Marine Corps Program Office, the Air Force Agency for Modeling and Simulation [AFAMS], the Institute for Simulation and Training [IST], and the Training and Simulation Technology Consortium [TSTC]) immediately signed on as Charter Members. The *Team Orlando* Charter outlines the synergy of the group as they recommit themselves to "work together to share information and leverage programs and technology in the best interest of the Department of Defense and the American taxpayer."

IST/UCF Dynamic Terrain Area of Visual Systems Laboratory.

Origins

Dating from the 1950s two Services, the U.S. Army and the U.S. Navy, built and enjoyed a special relationship in the M&S community. The informal concepts behind this relationship are the basis of *Team Orlando*. The success of this formula provides a history of mutual benefits for both Services. Today STRICOM and the Naval Air Warfare Center Training Systems Division (NAWCTSD) benefit greatly from a matured inter-Service relationship affording each entity the full benefits of leveraged resources, manpower, and

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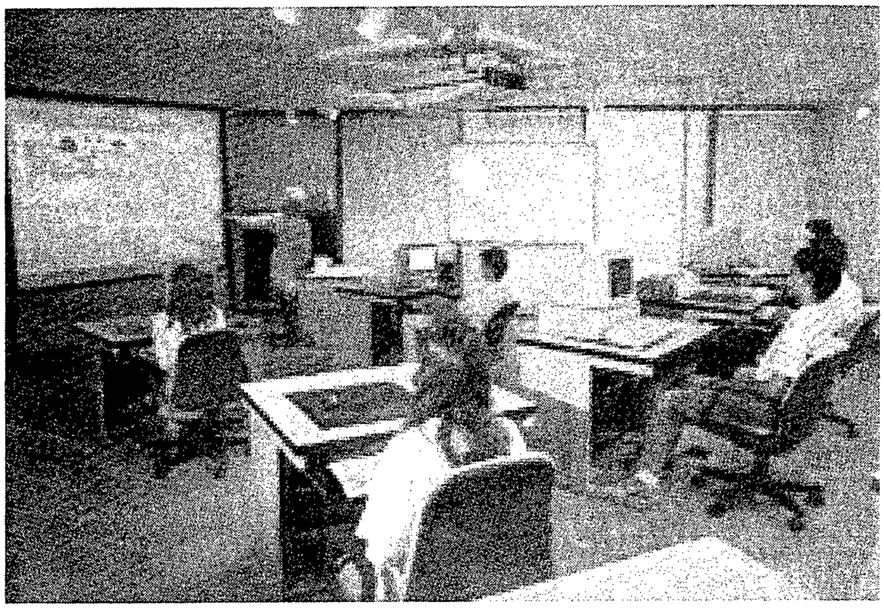
Digital photos/slides courtesy IST/UCF

IST/UCF ADVANCED LEARNING TECHNOLOGY TRANSFER CENTER CLASSROOM.



technological expertise, creating a strong foundation of success and the springboard for joint projects, such as JSIMS. The Marine Corps Program Office, another tenant of NAWCTSD, works as the principal representative for ground and air M&S programs impacting the U.S. Marine Corps. The U.S. Air Force, also seeing the benefit of leveraging the resources in the area, established the Air Force Agency for Modeling and Simulation (AFAMS) in Central Florida and plans to grow this organization in the next few years.

The State of Florida recognized this growing industry by establishing the Institute for Simulation and Training at The University of Central Florida (IST/UCF) in 1982. The IST provides a common source of academic studies and research in support of the M&S community.

In 1985, the Governor and Cabinet of the State of Florida issued a resolution recognizing the "Center of Excellence for Simulation." Today, Enterprise Florida, as the state's economic development unit, recognizes the significant contribution of STRICOM, NAWCTSD, the Marine Corps Program Office, and the growing AFAMS as the mainstays of the Center of Excellence.

In 1993, as further testament to the capability of this unique M&S community, the TSTC was established under the White House Technology Reinvestment Project. The TSTC was chartered to be a non-profit, one-stop source for all commercial applications of these sophisticated military and space M&S technologies.

Team Orlando in Action — DoD Membership

Over 1700 M&S professionals, representing the four primary uniformed services of the United States, comprise the government contingent of *Team Orlando*. The relationships and integration between and among these dedicated professionals is where the benefits of leveraging begin. Cooperative efforts between these government professionals, industry, and academia work to realize the benefits for the warfighter and the taxpayer.

One of the best examples of the *Team Orlando* concepts in action is exemplified by the symbiotic relationship between STRICOM, NAWCTSD, and the Marine Corps Program Office. The organizations share facilities, with STRICOM and the Marine Corps Program Office as tenants. STRICOM and the Marine Corps Program Office buy various types of base operations/infrastructure support services, and work years of contracting and engineering talent from NAWCTSD. This arrangement benefits all three organizations by sharing expertise, techniques, and methodologies, further enhancing integration and synergy among the Services.

The growing U.S. Air Force presence in this national simulation superstructure promises an additional potential to develop systems that combine the best of the Services. The mission of AFAMS is to implement DoD, Joint, and Air Force M&S Policy/Standards and provide Service-level M&S support to Joint, Combined, and Air Force Activities. This office also supports Air Force and Joint Wargaming Exercises, and supports other major joint M&S initiatives, such as the Joint Modeling and Simulation System (JMASS). Clearly, the synergy provided by *Team Orlando* will be vital as AFAMS, STRICOM, and NAWCTSD support and manage the development of joint synthetic battlespace and advanced distributed simulations of their respective Service customers.

Additionally, the JSIMS mission provides Commanders in Chief and the Services with next generation training, mission planning, and mission rehearsal capabilities. The JSIMS Joint Program Office values the benefits of the external joint community and the synergy created under *Team Orlando*.

The DoD members of *Team Orlando* also include representatives from Army Research Institute, Army Research Laboratory, Army National Guard, JSIMS Maritime, U.S. Naval Reserve, U.S. Marine Corps Reserve, Air Force Materiel Command Operating Location, and representatives from our NATO allies in Germany and the United Kingdom. Each of these organizations capitalize on the opportunity to use M&S solutions to their full advantage in fulfilling their individual missions.

Other Government Agency Membership.

In the spirit of *Team Orlando*, STRICOM and National Aeronautics and

Space Administration (NASA) recently signed an Interagency Agreement for Technology Cooperation. This agreement serves as a foundation for a more lasting technology transfer program and continuous business relationship. By cultivating this business relationship, STRICOM and NASA promote appropriate simulation and related technology for national Service, space, and other applications. Delineated in the agreement is the sharing of information, technologies, methodologies, consultation, and other services; and working toward further collaboration of efforts involving simulations, simulators, and instrumentation technology and methodologies. Also included are joint research or specific projects, whenever possible.

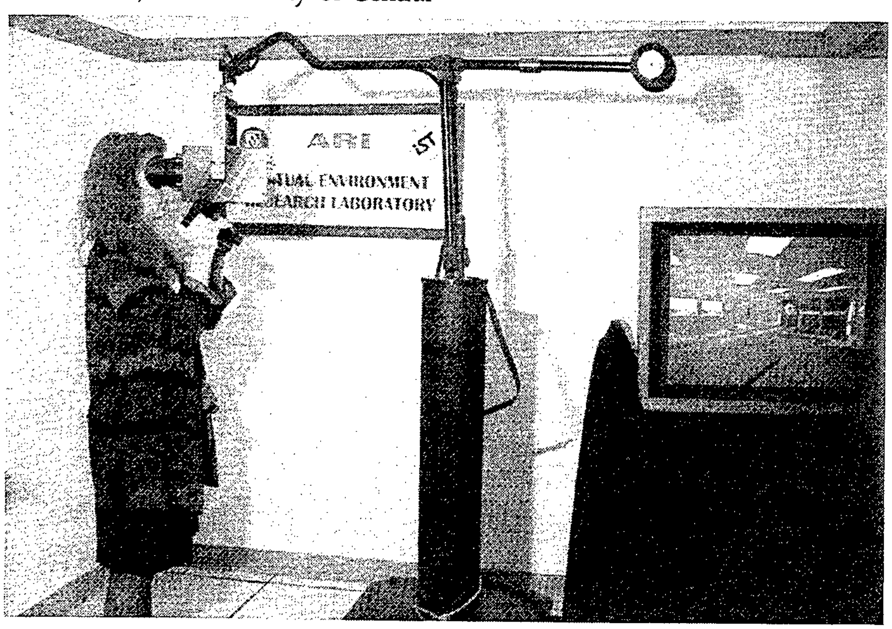
The Florida High-Technology Corridor Council and Enterprise Florida are working together with STRICOM, NAWCTSD, and approximately 150 companies involved in modeling, simulation, and training activities in Central Florida to provide for continued growth and recognition of the importance of this national asset. This national simulation superstructure, guided by the concepts of *Team Orlando*, is growing and attracting new simulation interests every year.

Academic Membership

Located adjacent to STRICOM and NAWCTSD, the University of Central Florida (UCF), Institute for Simulation and Training (IST) works to fulfill its mission as a resource and focal point for simulation and training technologies. The synergism generated through *Team Orlando* enables IST to play a key role in advancing the art of simulation and training technologies and the transfer of those technologies to the civilian sector. These efforts enhance our society and get the most return from research dollars.

As a charter member of *Team Orlando*, UCF takes an aggressive interest in simulation and training. The first university in the nation offering a master's degree in simulation, UCF is currently developing a Ph.D. program.

As a charter member of *Team Orlando*, UCF takes an aggressive interest in simulation and training. The first university in the nation offering a master's degree in simulation, UCF is currently developing a Ph.D. program. DoD employees are encouraged to take full advantage of these resources.



IST/UCF Virtual Environment Testbed.

Industry Players

DoD *Team Orlando* members have significant involvement with many of the 150 commercial industry partners located here in Central Florida. Many serve as a contractor or subcontractor on crucial DoD programs, supporting $1 billion in contracts annually. As we partner with local industry, *Team Orlando* DoD members benefit from the unique opportunity to take advantage not only of federal Acquisition Reform initiatives, but also reap the rewards provided by the synergy created by this simulation superstructure.

Many other industry players are embarking with *Team Orlando* on a journey toward dual-use exploration. For example, STRICOM and the Walt Disney Company, the premier expert on the use of M&S in the entertainment industry, have an ongoing relationship exploring dual use and technology transfer opportunities.

The mission of TSTC is to assist private/commercial industry to acquire simulation and training technologies and capabilities previously available only to the U.S. military and space effort. TSTC membership includes

STRICOM, NAWCTSD, AFAMS, NASA, IST, and over 20 private companies. One project under exploration by the TSTC is a regional transportation planning system, for which the technology is applicable to the national defense and its readiness, as well as federal, state, regional, and local transportation planners. TSTC is also exploring other simulation and training projects with the American Red Cross, Universal Studios, Kennedy Space Center, and the Federal Emergency Management Agency (FEMA).

The work of TSTC – to raise awareness and facilitate technology transfer and jobs – clearly make it an asset to *Team Orlando* by sustaining the defense industrial base upon which the Department of Defense must rely for affordable, state-of-the-art M&S technology development and applications.

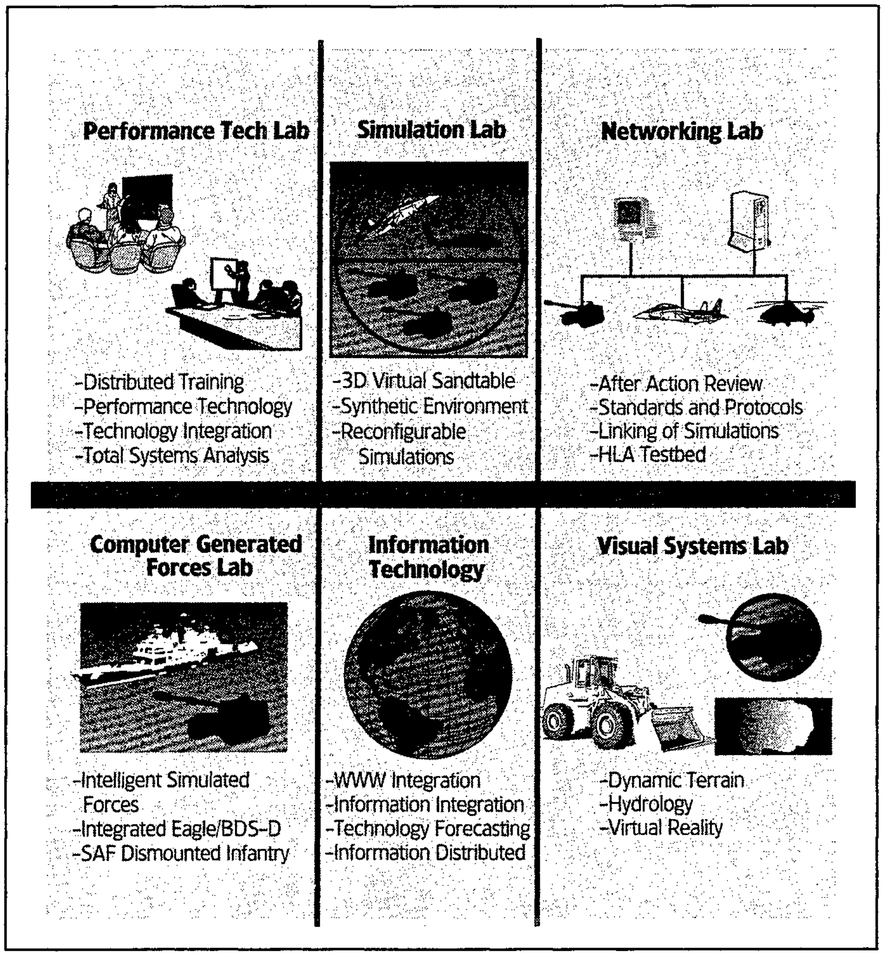
Recognized Results

As a member of this national simulation superstructure – *Team Orlando* – success is multiplied among all the members. This national simulation superstructure provides DoD with an enormous, technologically advanced support unit. Our contractors provide us with better products through retention of highly skilled jobs, advancements in the M&S industry, and academic support for the technical educational needs required by the simulation industry.

The value of this national simulation superstructure, led by *Team Orlando*, can be seen daily in many areas:

- Growing Number of High-Technology Jobs
- Reduced Cost for DoD End Items
- Shorter Time from Technology Development to End User Applications
- Number of Strong Bidders for DoD Contracts
- Number of Cooperative Research and Development Agreements (CRADA)
- Grants And Cooperative Agreements Integrating Collaboration in Research and Development

THE INSTITUTE FOR SIMULATION AND TRAINING AT THE UNIVERSITY OF CENTRAL FLORIDA (IST/UCF) PROVIDES A COMMON SOURCE OF ACADEMIC STUDIES AND CONDUCTS RESEARCH IN SEVERAL DOMAINS FOR THE DOD MODELING AND SIMULATION WORKFORCE.



Team Orlando members plan to continue to expand these contacts and agreements, leveraging and enhancing the innovations being developed by and between the growing membership of the team for the overall long-term benefit of all.

This growing force of government, industry, and academia M&S experts share a common vision for the future of M&S and its recognized development. The continued success of *Team Orlando* is vital to the shared goal of cost reduction by leveraging of DoD M&S dollars. By working to preserve and advance the industrial base, increase the willingness of industry to invest their R&D efforts in M&S, foster innovative applications of the latest technology, and leverage the numerous M&S projects in other areas, the Department of Defense, through the efforts of *Team Orlando*, can maintain its technological superiority at a reduced cost into the future.

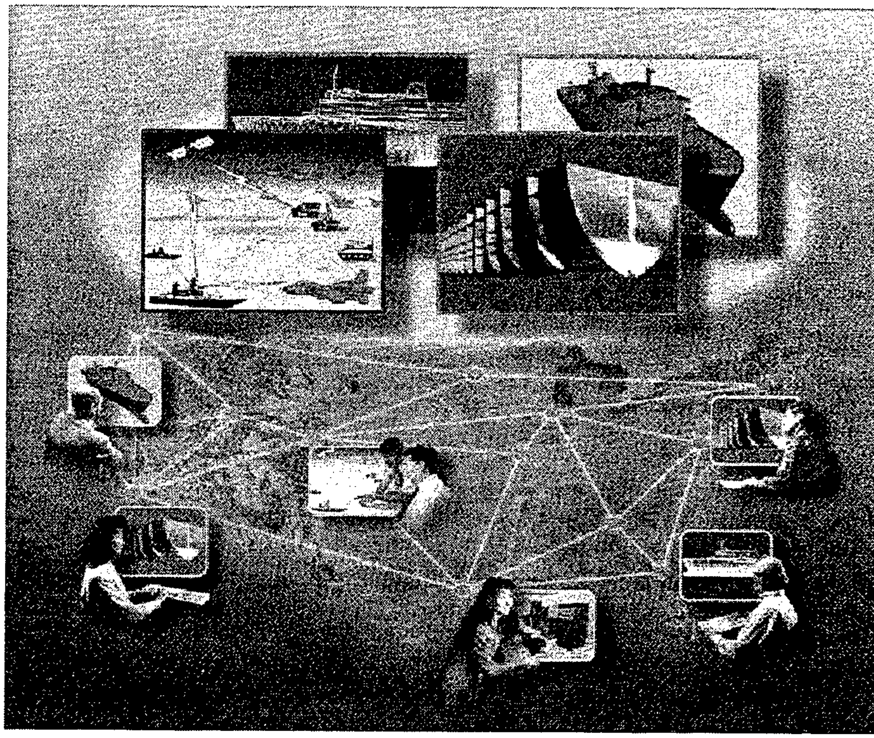
The *Team Orlando* model is a success story. If fostered, it will assure the nation a network of highly qualified companies ready and able to develop superior M&S technologies and products for the Department of Defense. As written in the STRICOM crest, "All But War Is Simulation." These state-of-the-art, "make believe" M&S solutions will provide the warfighters of tomorrow, operating under the concepts of *Joint Vision 2010*, with capabilities to ensure the success of U.S. Forces into the next millennium.

Integrated Ship Defense Modeling and Simulation Pilot Program

If PMs Bring M&S Into Focus DoD-Wide, They'll See a Real Return on Investment

LORRAINE SHEA • MICHAEL POBAT

Can modeling and simulation (M&S) truly be a highway for the program manager to navigate the road to project success over the life cycle? Currently, the acquisition community is embracing Simulation Based Acquisition (SBA) initiatives, but where is the evidence that there is a payoff here? Where is the real value-added?



Traditionally, program managers navigate the life-cycle process in different ways using a variety of available tools, including M&S. So what is new here? What is this M&S revolution all about?

As a system grows throughout the engineering and development phase, SBA – when used by the engineers who are designing the system and the platform it will ride on; analysts performing trade studies and investment analyses; and testers responsible for certifying the design meets specifications – allows a conceptual model to grow in functionality and increasing specification. The end result is a well-understood, credible representation of that system, capable of augmenting developmental and operational testing. This same model can then be passed to the in-service and training community for use during deployment and Pre-Planned Product Improvements. Although the level of abstraction of the basic model may change from application, a pedigree is established based on a common system representation that becomes the standard for any application. Hence, an adaptive life-cycle tool evolves for the program manager.

Program managers then, gain the benefit of a readily available engineering model of the system that assists in the design and development process, and is reusable and interpretable, not only with other elements of the overall system, but with the entire technical and operational community. Regardless of the design agent, laboratory, field activity, or Fleet installation, the foun-

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Pobat is the Integrated Ship Defense Program Manager, Weapon Systems Division, for Litton/PRC, Inc., located in Arlington, Va. For the past five years, his work with the Navy's PEO(TAD) has included Ship Self Defense investment strategy development and modeling and simulation. Pobat previously spent 10 years in the Navy as an Electronic Warfare Technician, with tours aboard the U.S.S. Biddle *(CG-34), U.S.S.* Austin *(LPD-4), and U.S.S.* Sterett *(CG-31). Homeported in Subic Bay Philippines for two years, he also completed tours at various stateside shore stations.*

dation exists for the operation of and interaction between the system models. When you begin to think of the flexibility SBA allows and the time it can save, the payoffs become evident. Ultimately, SBA enables us to develop, field, and support the best products to the operational community in a more cost-effective way.

Current technology can support this revolution. Now is the time for the acquisition community to be creative and integrate this technology with sound engineering practices.

Selection of the Pilot Program

In 1995, the Program Executive Office (Theater Air Defense) (PEO[TAD]) Technology Directorate proposed a set of Advanced Distributed Simulation (ADS) Pilot Programs that was, in part, prompted by the 1994 Naval Research Advisory Committee (NRAC) study. The NRAC study endorsed the use of ADS in support of the acquisition process and stated that "DoN [Department of Navy] acquisition that would provide good candidates for Distributed Simulation Based Acquisition (DSBA) are mine countermeasures, sea-based Theater Ballistic Missile Defense (TBMD), and Ship Self Defense." Based on these differing mission areas, the PEO(TAD) proposed three specific programs as potential pilot programs: Integrated Ship Defense (ISD), TBMD, and Overland Cruise Missile Defense. Ultimately, the Navy selected the ISD Pilot because it represented the most mature and current Fleet sensor/weapon system.

In May 1996, the Office of Naval Research tasked PEO(TAD) to further develop the ISD Pilot Program concept and provide a detailed program plan. A team consisting of representatives from PEO(TAD), Naval Surface Warfare Center Dahlgren, Naval Research Laboratory, Johns Hopkins University/Applied Physics Laboratory, the Mitre Corporation, and PRC Inc., provided the necessary subject matter experts for the task. Completed in September 1996, the ISD Pilot Program Plan provides the detailed technical and programmatic aspects. To generate support and solicit feedback on the proposed ISD Pilot Program, the team conducted a series of key briefings to solicit feedback, guidance, and support from key DoD/DoN senior civilian and military personnel. As a result, they gathered enough information from the following offices to transform the Pilot Program Plan into an executable program:

The sneaker net is literally the human-in-the-loop, which hand-carries the results of one model to the operator of the next. This process is labor- and time-intensive and does not capture many benefits inherent in the SSDS and QRCC.

- Office of the Secretary of Defense (OSD) Director of Research and Engineering
- OSD Director of Test Systems Engineering and Evaluation
- Assistant Secretary of the Navy for Research, Development, and Acquisition (C^4I)
- Defense Modeling and Simulation Office
- Chief of Naval Operations
- Director of Navy Test and Evaluation and Technology Requirements (N091)
- Navy Modeling and Simulation Office (N6M)

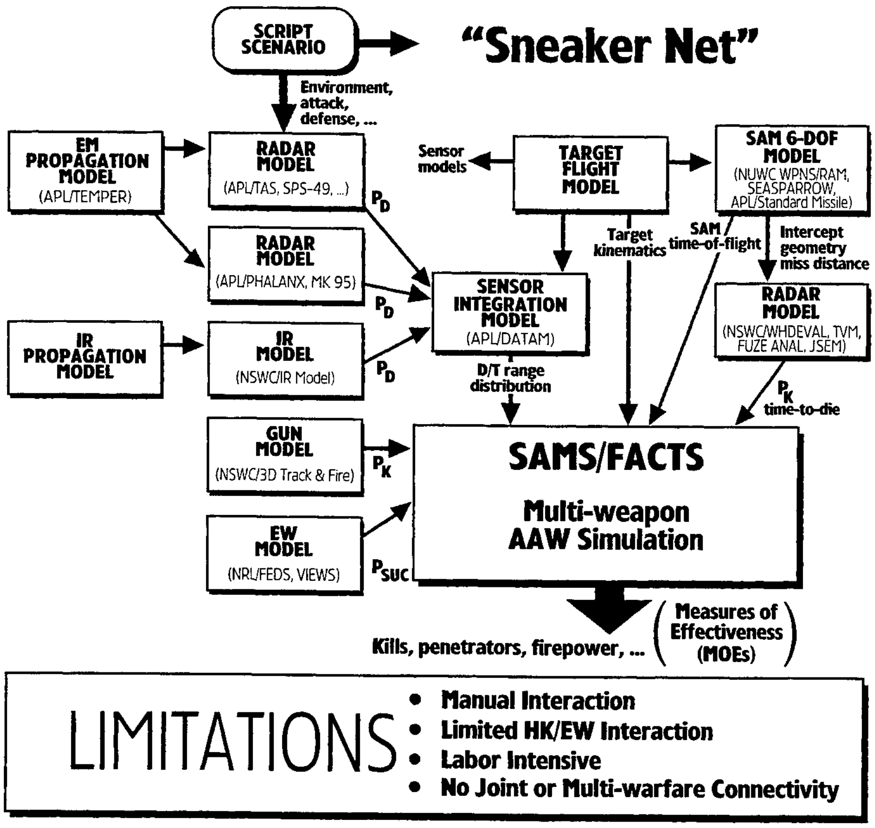
ISD Program Description

The Chief of Naval Operations approved a plan for development of a Quick Reaction Combat Capability (QRCC) to improve defenses against anti-ship cruise missiles for non-AEGIS ships, and to assure greater survivability for ships operating in harm's way.

To effectively defend against an increasingly stressing cruise missile threat, the operator requires an automated detect-through-engage capability with reduced reaction time. The operator then has the capability to associate and correlate multi-sensor data to provide a sensor-fused composite track that assures a high level of certainty in target identification and classification. Use of flexible doctrine that supports layered defense engagements provides the operator automated control of the system functions and actions. Once the system presents and displays the information such that the operators have an accurate, precise, and comprehensive picture of the tactical situation, the operator can then override, abort, or alter doctrine as necessary. Ultimately, the intent is to provide a fully automated ISD capability.

The ISD combat system provides automated detection-control-engagement by integrating existing stand-alone weapons and sensors via the Ship Self Defense System (SSDS) MK-1. Such integration involves a series of automated actions/reactions:

Figure 1. **The "Sneaker Net"**



- Existing sensors detect targets and provide track data to distributed track file processors via a Local Area Network (LAN).
- Each track file processor correlates and associates track data for use by the SSDS in Sensor Integration and Control processors, which assign and manage common track file numbers.
- The Local Command and Control processor determines target identification, classification, and appropriate action.
- The Weapon Integration and Control processors manage scheduling. Providing a layered defense that ensures the best employment of hardkill and electronic warfare (HK/EW) segments, these processors automatically determine the weapon(s) mix required to defeat the threat.

Current ISD M&S Capability

The ISD Pilot Program includes a federation of interactive hi-fidelity models built upon and from the existing family of credible, authoritative (although primarily stand-alone) ISD M&S. Separate program offices originally developed these legacy M&S to aid engineers in design, development, test and evaluation (performance prediction), and planning. With the formulation of the ISD program office and a focus on the integrated combat system operation, a need surfaced to integrate the models as well. A team of subject matter experts from various laboratories and government facilities manually integrate the models and conduct combat-system-level analysis such as Program Objectives Memorandum investment strategies; cost and operational effectiveness analyses (COEA) or Assessment of Alternatives (AOA); and selected ship-class performance capability studies. This manual integration is known as "the Sneaker Net" (Figure 1).

The sneaker net is literally the human-in-the-loop, which hand-carries the results of one model to the operator of the next. This process is labor- and time-intensive and does not capture many benefits inherent in the SSDS and QRCC. The current M&S capability, although sufficient for the applications mentioned, does not provide the level of fidelity and operational realism required for the SBA environment (i.e., common battlespace, reactive threat, jamming, realistic equipment availability, hi-fidelity modeling of Electronic Warfare/Infrared (EW/IR), Hardkill/Electronic Warfare (HK/EW), and common standardized databases that are usable by all interactive simulations).

The demand for more operationally realistic M&S capability (e.g., threats, system availability, environment, etc.), a deeper understanding of HK/EW layered defense, and a means of integrating geographically distributed engineering models and subject matter experts, highlight the need for a new approach to M&S.

ISD Technical Issues

The ISD Pilot Program addresses the shortfalls of the existing M&S capabilities (i.e., the Sneaker Net). Improvements incorporate reactive threats and operational environments to increase the realism and credibility of the results. As a first step, it builds upon an established set of existing engineering-level models with known capabilities, by linking them together via a High Level Architecture-compliant Run-Time Infrastructure (RTI). Ultimately, the ISD Pilot Program must address the following technical issues:

- Evaluate and quantify weapons and threat interaction (performance) with the environment (reactive threat, dual mode RF/IR).
- Evaluate and quantify weapons interaction (performance) with the threat.
- Evaluate and quantify sensors' interaction with threat and environment.
- Evaluate and quantify HK envelopes for probability of kill.
- Evaluate and quantify HK and EW weapons interactions and effectiveness.

- Generate accurate and repeatable system analysis data for ISD verification and isolation of problems.
- Evaluate and quantify system effectiveness using performance measures.
- Create a common-usage, controlled environment for demonstration of system modifications and standardization of threat, environment, and scenario representations.

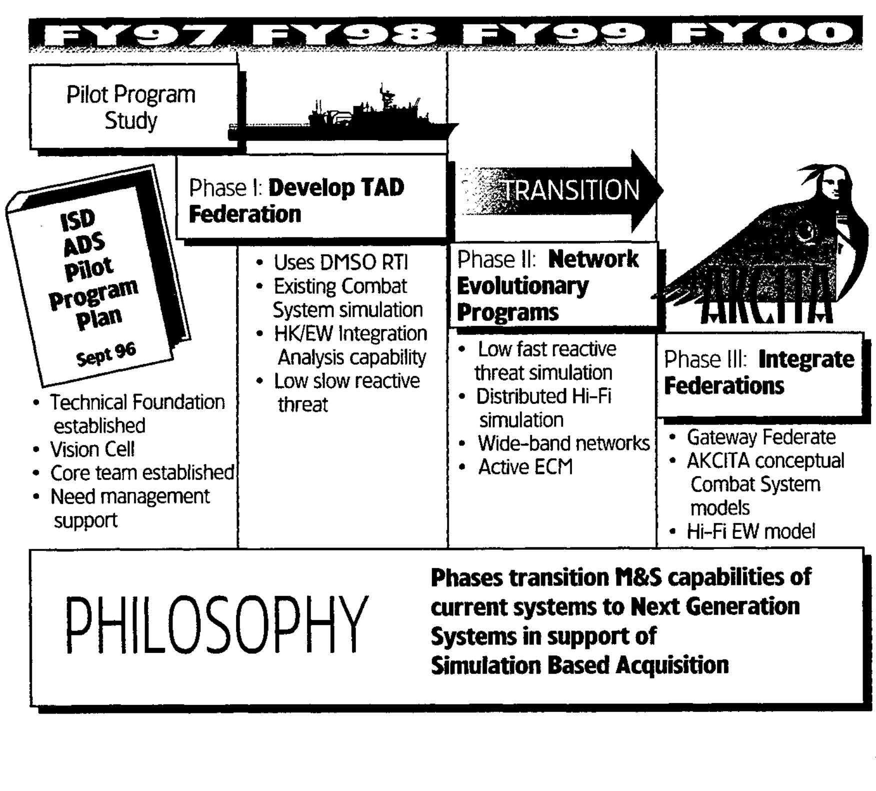
Program managers must address and solve these technical issues through a thorough understanding of the capabilities, limitations, and interactions of a number of diverse weapons and sensors in complex land, sea, and littoral environments. To evaluate system performance, hi-fidelity, physics-based engineering simulations must reflect these complex system interactions as well as dynamic environmental effects. Consideration of these interdependencies between sensors and weapons; weapons and threats; and between sensors, weapons, and the environment, dictates a departure from the traditional isolated system and subsystem engineering analyses and simulations.

In the past, program managers studied these interdependencies in the real world, through expensive exercises and testing. Regrettably, in many cases the complexity of today's weapons systems surpasses the affordability of complete testing in real-world exercises. The simulations proposed for the ISD Pilot Program will provide the capability to conduct a large part of these analyses and evaluations without expending costly ship, personnel, and test and evaluation resources, and lay the groundwork for advancing SBA initiatives.

ISD Pilot Program Overview

The goal of the ISD Pilot Program is to develop and demonstrate a comprehensive M&S capability that supports the design and evaluation of components and systems, which further support SBA initiatives. The ISD ADS Pilot Program will be conducted over a period of three years. Each phase will retain its own set of objectives; however, each phase will build on the capabilities demonstrated in the preceding phase. Figure 2 shows the three phases of the program and the evolving capabilities. The goal is to increase the simulation set and proceed toward the eventual implementation of the superset of simulations. A brief description of each phase follows.

Figure 2. **Evolving Capabilities**



Phase I

The development team intended that this initial phase provide a benchmarking opportunity in the development of ISD Federation. Accordingly, the system designers, modelers, and testers will be addressing the complex issues inherent to test and evaluation. Of particular interest is the ability to perform HK/EW integrated modeling in a distributed environment using a High Level Architecture-compliant RTI. For this reason, the approach is conservative and is tailored to achieve the greatest capability in a one-year time period. This time period will still permit the development team to gain the experience needed to accomplish more complex configurations in subsequent phases. To minimize risks, the simulations will be developed at the developer's site. The integration, however, will be accomplished in a single laboratory, with the simulations interconnected via RTI, but using a LAN. The products of Phase I are –

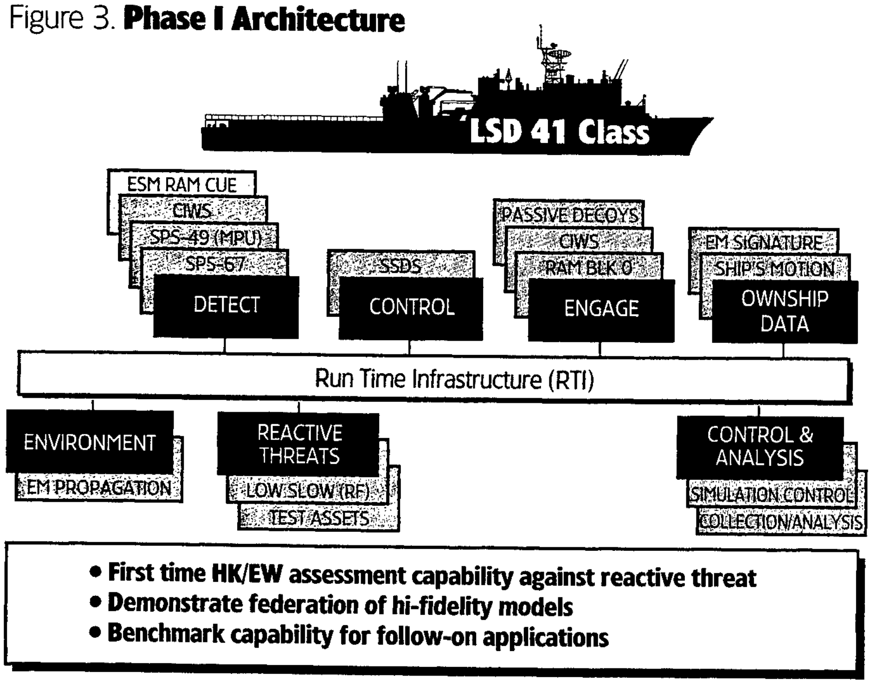
- first-time, hi-fidelity detect-through-engage simulation capability;
- hi-fidelity, integrated HK/EW assessment capability;
- threat reactive-common to all combat system elements;
- contribution to Joint Synthetic Test and Evaluation battlespace;
- established foundation for Phases II and III;
- PEO(TAD) established as a beta test site for Defense Modeling and Simulation Office RTI; and
- verification and validation of federation.

Figure 3 depicts the architecture for Phase I development.

Phase II

The intent in Phase II is to use the experience gained in Phase I to greatly increase the capability of the federation through the incorporation of additional federates. This com-

Figure 3. **Phase I Architecture**



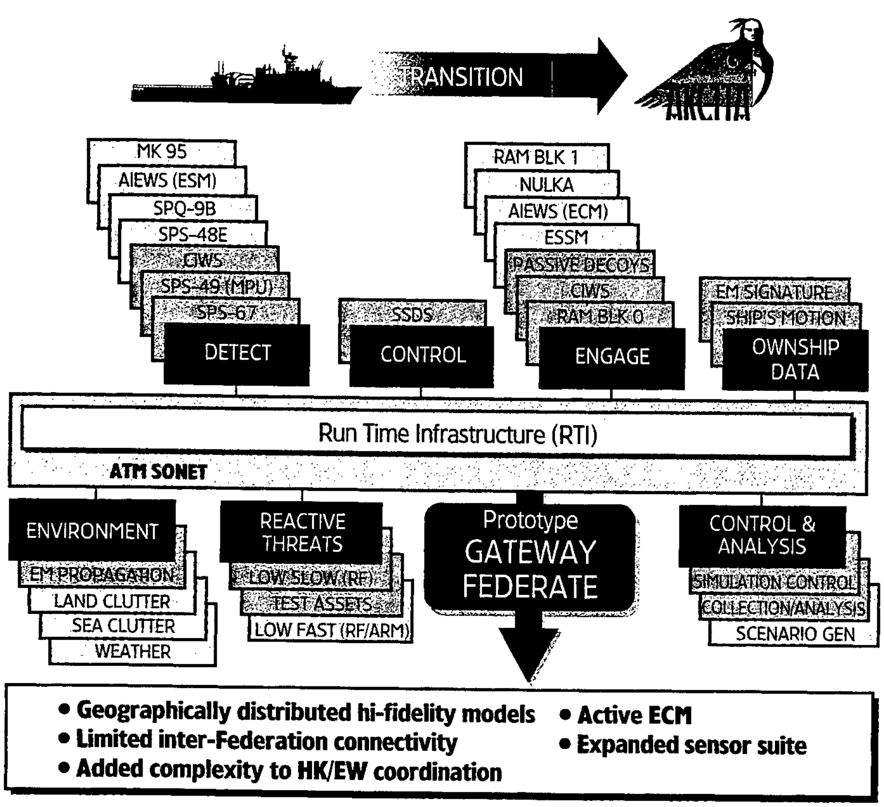
plexity will enable a close examination of sensor integration and will permit a systematic approach to the investigation of HK/EW coordination. Models involved in this phase will reside at the developer's site and will be interconnected, through the RTI, via a geographically distributed network.

Additional reactive threats will be added in this phase. The intent is to add threats whose performance can stress the capabilities of the ISD combat system. In this way the federation can be used to explore reaction times of different combat system configurations to stressing situations. This will also permit an evaluation of the federation and its capability to simulate real-time operation. The products of Phase II are –

- active electronic attack assessment;
- realistic representation of operational environment;
- geographically distributed simulation using Asynchronous Transfer Mode/Sonet Network;
- network technology that provides feasibility of a re-use tool;
- verification and validation of federation; and
- additional threat families represented.

Figure 4 depicts the architecture for Phase II development.

Figure 4. **Phase II Architecture**



Phase III

The intent of Phase III is to produce a federation that provides a capability to model conceptual systems of the next generation combat system – Akcita. This will enable the federation to support SBA initiatives for future acquisition programs.

To provide a realistic operational environment, this phase will complete the addition of propagation, clutter, and weather models to achieve a dynamic multispectral environment. This will enable the examination of both Radio Frequency (RF) and Infrared (IR) threats in a stressing environment. To provide detection of these dual-mode threats, this phase also adds an IR sensor.

The Gateway Federate will be employed and tested in this phase, enabling communication and interaction between two federations of differing levels of fidelity and resolution. The intent is to link the ISD Federation to the Joint Countermine Operational Simulation (JCOS) Federation to simulate a multi-warfare exercise.

This would permit inter-federation communications between a federation operating with engineering-level simulations and a federation operating at an engagement simulation level (i.e., lower fidelity). Phase III products include –

- IR sensor, environment, and threat modeling;
- conceptual ship and combat system models;
- advanced threat models (full complement of ISD threat representative models);
- advancement of SBA initiatives through multi-fidelity simulation;
- inter-federation linking (Gateway Federate); and
- verification and validation of federation.

Figure 5 depicts the architecture for Phase III development.

Value-Added and Support to Acquisition Program Manager

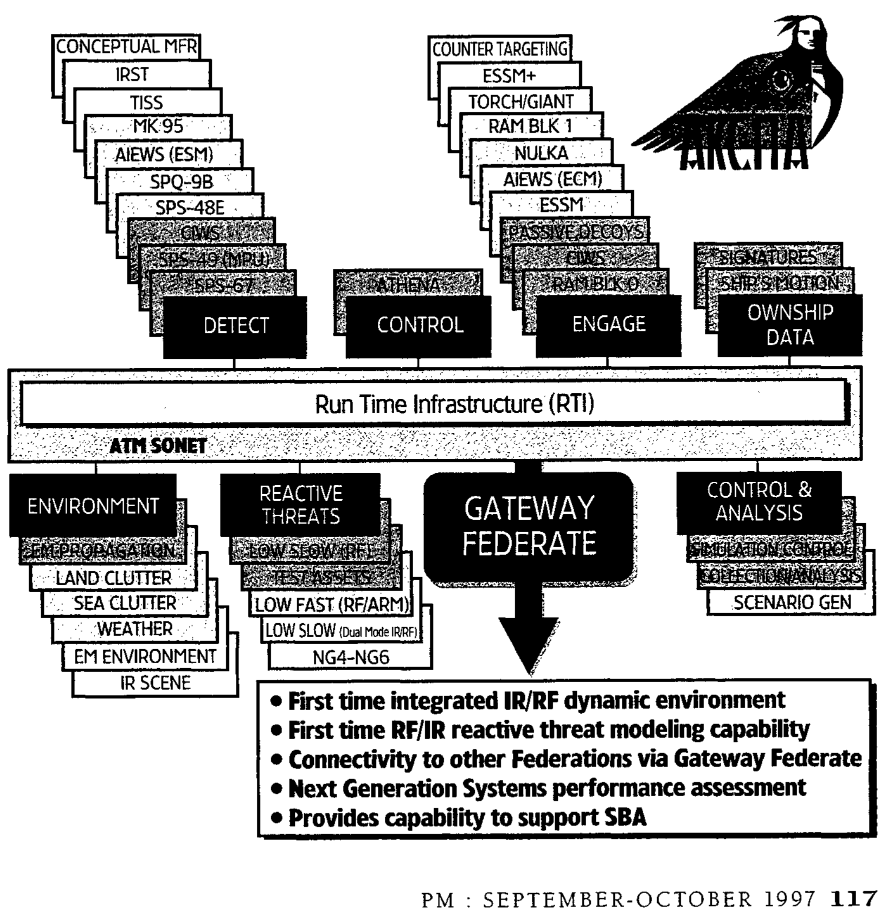
The tools resulting from completion of the Pilot Program have the potential to enhance the system acquisition process by adding value in the following areas:

- **AOA.** The federation of ISD analytical models can be used to determine operational effectiveness against specified threats as part of an AOA Study.
- **Mission.** As a means of developing a Requirements Definition, the simulations provide a means for quantitative evaluation of measures of effectiveness and performance prior to verifying system requirements.
- **System Engineering.** The Interactive ISD Federation will provide a mechanism for developing and exercising a prototype system in a simulated environment. This will, in effect, create a laboratory for trying out a design or an engineering change proposal, before its approval as an engineering requirement.
- **Design and Analysis.** The simulations provide a mechanism for the collection of performance data as a basis for design of system modifications. A significant feature is the ability to conduct repeatable test conditions, and the capability to parametrically vary the conditions in a controlled manner.
- **Testing and Evaluation.** The ISD Federation will provide a virtual simulation capability that will enhance test and evaluation efforts by providing better-designed systems as a result of testing earlier in the development phase. A wider scope of testing may be possible for some systems, especially those that require large scenarios of costly test services, such as multiple aircraft flyovers or test targets and associated range services.
- **Doctrine and Tactics.** The ISD Federation will provide a method to evaluate the tactics and doctrine by exercising the prototype ISDS human-machine interface in conjunction with the simulated sensors and weapons.

Bringing M&S Into Focus

The key issue for program managers to understand is that as M&S is brought into focus DoD-wide, the real return on investment will be realized. Because of declining budgets and technically advanced systems, we can no longer continue business as usual and expect to field the same quality systems. We must rely more on the benefits M&S can provide, but first we need to lay the foundation that makes that possible. Program managers need to have a high degree of confidence in their models and the subject matter experts to operate them. The key is to get started, take a small piece of the problems, and work from there. The momentum of success and opportunity to leverage from other's work will carry the effort forward. Every effort toward this goal helps by bringing M&S into clear focus for the acquisition community.

Figure 5. **Phase III Architecture**



Integrated Acquisition-Logistics Synthetic Environments for Total Value Assessment

Reuse and Interoperability of Virtual Products Key to Payoff on a National Scale

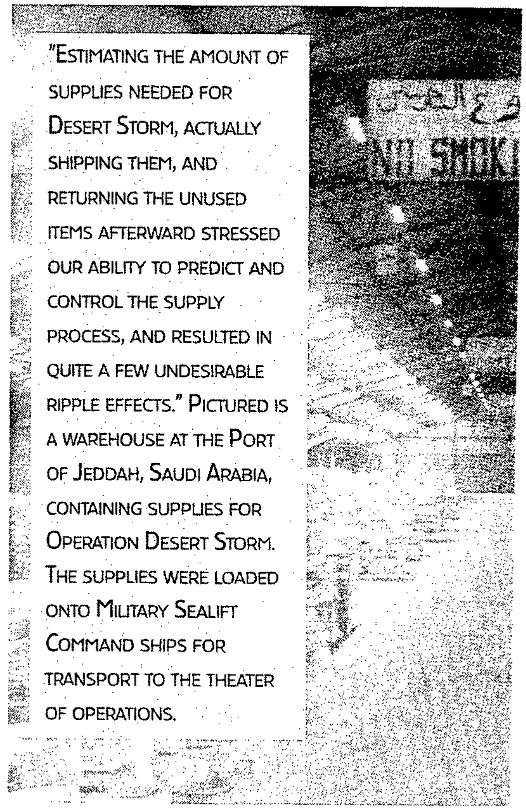
GARY JONES • HENSON GRAVES • MARK GERSH

Total Value Assessment for the acquisition, delivery, provisioning, and sustainment of warfighting forces requires a greater understanding of how these processes develop, interrelate, and evolve in real-world situations. These processes are complex and tend to depend upon an immense amount of data. In many cases, small changes in the environment produce large discontinuous changes in the way the processes work. For example, estimating the amount of supplies needed for Desert Storm, actually shipping them, and returning the unused items afterward stressed our ability to predict and control the supply process, and resulted in quite a few undesirable ripple effects.

Vision

Creating models for acquisition-logistics processes and simulating their execution within a synthetic environment provides the best tool available for assessing the total value of products and their associated processes. Within a synthetic environment, we can instrument and monitor an unfolding process and its constituent product(s) to gather data for later analysis; or in real time, interactively ask "what-if" questions by making adjustments to the product(s) and process(es) to better understand resultant behavior.

Creating models for acquisition-logistics processes and simulating their execution within a synthetic environment provides the best tool available for assessing the total value of products and their associated processes.



"ESTIMATING THE AMOUNT OF SUPPLIES NEEDED FOR DESERT STORM, ACTUALLY SHIPPING THEM, AND RETURNING THE UNUSED ITEMS AFTERWARD STRESSED OUR ABILITY TO PREDICT AND CONTROL THE SUPPLY PROCESS, AND RESULTED IN QUITE A FEW UNDESIRABLE RIPPLE EFFECTS." PICTURED IS A WAREHOUSE AT THE PORT OF JEDDAH, SAUDI ARABIA, CONTAINING SUPPLIES FOR OPERATION DESERT STORM. THE SUPPLIES WERE LOADED ONTO MILITARY SEALIFT COMMAND SHIPS FOR TRANSPORT TO THE THEATER OF OPERATIONS.

A major DoD Modeling and Simulation (M&S) objective is to perform virtual warfare engagements using simulated and actual weapon systems. This vision and its objectives can be broadened to include the acquisition and logistics processes of simulated and actual systems. For example, a logistics planning exercise using weather and climate data may link to actual operational supply vessels and into

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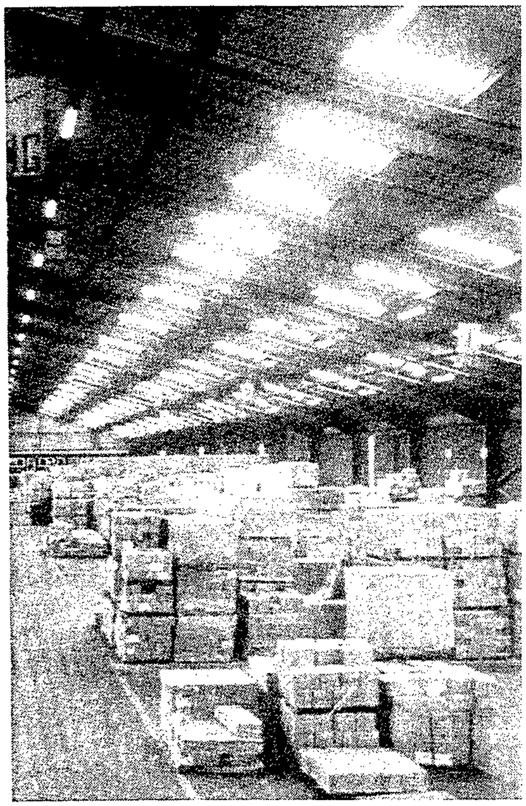
Photo by PH2 Milton R. Savage, USNR

commercial transport systems so as to assess the trades of augmenting DoD systems with commercial delivery systems. Imagine if this same exercise included connections to models and simulations of the transported products so the issues of retrofit and manufacturing could also be addressed, giving logisticians an even more complete or total value assessment of all options.

Achieving the Vision

Achieving the vision of integrated acquisition and logistics synthetic environments still presents a number of technology challenges. Before vir-



tual engagements can be of most value to life-cycle analysis, they will require high-fidelity system models. During the course of analysis, we need an ability to refine components of high-level aggregate models into detailed high-fidelity models to better explore specific aspects of a life-cycle problem. M&S is already used for planning and warfare analysis at different levels of abstraction (campaign, engagement, and system interoperation); however, current M&S systems have little ability to integrate multiple-fidelity models into a simulation exercise.

No single organization will be able to build and maintain the collection of virtual prototypes needed for these exercises. Since prototypes will be built and used by many different organizations, achieving interoperability requires the use of at least de facto standards and perhaps an organization to promulgate those standards. Currently, some standards are beginning to emerge for representing virtual prototypes. For example, modelers explicitly designed Virtual Reality Modeling Language (VRML) to produce virtual prototypes that can be placed in synthetic worlds and interact with other objects in these worlds. This emerging technology needs to be integrated and more exploited within the acquisition-logistics community.

Constructing and performing assessment exercises in a synthetic environment requires a distributed modeling and simulation framework in which a user can discover and configure virtual prototypes, then launch exercises without human involvement at any of the distributed sites that contain prototypes. Commercial technology and standards that address tool-to-tool communication (e.g., Common Object Request Broker Architecture [CORBA], Internet protocols) are available and can be exploited for the assembly of distributed synthetic environments.

SBD's Influence/Accomplishments

The Defense Advanced Research Projects Agency Simulation Based Design (SBD) program is developing a prototype distributive, collaborative software system that addresses some of the functions required for fielding the types of integrated acquisition-logistics synthetic environments that support the development, analysis, and interoperation of virtual prototypes.

Previously, DARPA's SBD program validated the feasibility of establishing distributed synthetic collaboration environments between multiple heterogeneous organizations. To meet new threats, these collaborative synthetic environments used *engineering* analysis to better evaluate operational warfighting performance and used operational analysis to reengineer weapon systems.

Engineers also used SBD to develop conceptual design models and detailed engineering models for ships. Of sufficient structural detail that modelers can use them for parametric design optimization, the conceptual models can be placed in high-fidelity operating environments. The detailed models have been used to generate shop floor manufacturing instructions and to provide immersive maintenance training.

During the past year, the SBD program performed a validation experiment, called the Advanced Surface Combatant (ASC), that culminated in a February 1997 demonstration of SBD maturity. This experiment specifically focused on the survivability analysis and redesign of a surface combatant to meet a new threat. It also provided the opportunity to include detailed physics-based models in the warfighting analysis phase and use of multidisciplinary optimization techniques to provide parametric design information to the redesign process.

The ASC Experiment resulted in an SBD system configuration that –

- integrated multiple companies and government agencies into an Integrated Product Team (IPT);
- organized the IPT as a hierarchical collection of federations;
- operated over a combination of Local Area Network, Internet, and DARPA gigabit testbed (ATDNet) network resources;
- integrated approximately 30 software components into the system;
- integrated two legacy databases and ingested the indicative design of the Navy SC-21;
- provided interface code that wrapped legacy simulations making them compliant with the DMSO High Level Architecture;

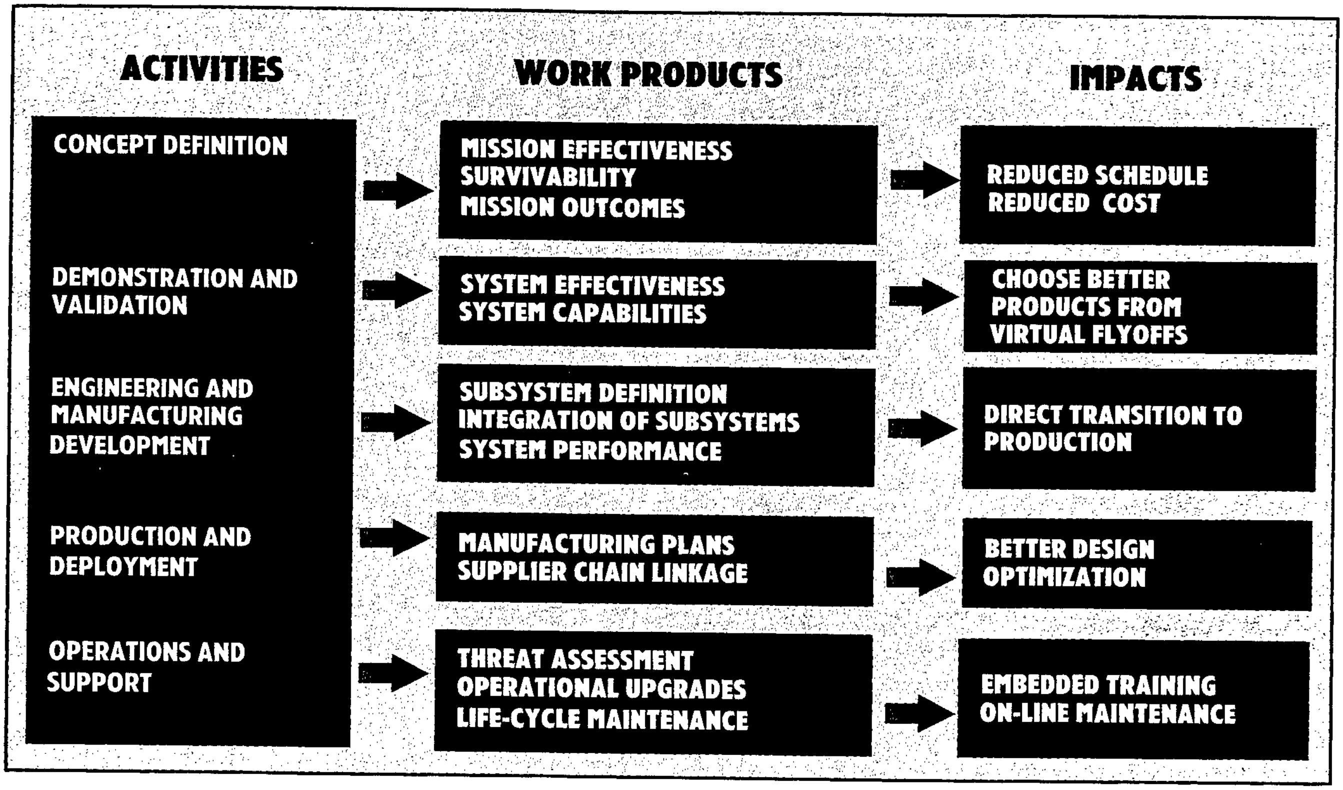


Figure 1. **Product Life-Cycle Activities, Work Products, and Impacts**

- demonstrated the use of SBD in multiple life-cycle activities (from requirements to training);
- demonstrated the use of multidisciplinary analysis and optimization; and
- incorporated cost as an independent variable in the design trades.

The ASC experiment represented a significant achievement in maturing SBD technology to the stage that it can now be deployed for experimental use by contractors and the government for conceptual system design, development, and evaluation.

The SBD Product

The SBD system is a collaborative, multidisciplinary environment for developing and using virtual/real prototypes. Engineers configure an SBD system for a specific application by linking copies of a common set of software, called the Core Processing System, together with application-specific software tools. SBD allows engineers to develop, analyze, and operate virtual prototypes as they would actual prototypes, but without the cost and complexity associated with real hardware and materials. A virtual prototype is a computer software module that models the structure and behavior of the actual product under development. The process of producing an actual product proceeds as a series of virtual prototypes that defines the product and/or generates manufacturing instructions for the product. For the virtual prototyping process to yield actual quality products, the same disciplines must be applied in the virtual prototyping process as are applied in conventional product development processes.

Numerous integrated development environments exist, tailored to a selected computer-aided design (CAD) tool (e.g., the Boeing 777 CATIA™-based environment), and many organizations have now integrated modeling, simulation, visualization, and analysis tools for product development. However, engineers craft these concurrent engineering systems for specific applications, which significantly limits their reusability, even between different projects in the same organization. Developing the second system becomes as expensive as developing the first. Further, there are no standards to allow these different systems to interoperate.

The SBD process employs a much more open approach that produces a variety of design, engineering, and evaluation results. Figure 1 illustrates the product development activities, SBD work products, and their impact on the product life cycle. This process delivers better quality products at a reduced cost, risk, and schedule when compared to the current, more conventional concurrent engineering approaches. The virtual prototyping activities can be conducted in a distributed collaborative software environment, which allows more concurrence in the development tasks, thus reducing schedule slippage.

Using virtual prototypes for engineering analysis and operational validation also allows for investigation of larger solution spaces. Changes can be made much later in the virtual product development life cycle without incur-

Figure 2. **SBD Integrates Multidisciplinary Life-Cycle Activities**

ring the cost magnitude that changes further downstream make in conventional development processes.

Figure 2 illustrates the life-cycle activities for a notional ASC Navy program, integrated and supported by a collaborative SBD system configured as an IPT. The IPT involved multiple government and contractor organizations with participants for program management, design, engineering analysis, operational test and evaluation, and deployment and training.

The ASC SBD system linked multiple copies of the common software components together to support the IPT. Engineers configured each participant's software to reflect one of the following four roles in the life-cycle development process:

- Program Management Office
- Hull Mechanical and Electrical Design
- Combat System Design
- Survivability Analysis

While some of the ASC software was ship-specific, much was domain-independent and could be used for other application areas. The experience of integrating such an SBD system translates readily to other domains.

Using SBD

With SBD, a user can define, modify, visualize, and manipulate virtual products. The SBD system coordinates the management between multiple user activities by using virtual prototypes that are composed as assemblies of subsystems and parts. Engineers define the actual construction of parts in terms of material, structure, and behavior attributes. By combining legacy models in various ways and by producing data that can be used by a variety of legacy analysis tools, they construct virtual products. The values then, of these attributes may be computed by external tools or incorporated from legacy databases.

Users access SBD through a standard web browser. Figure 3 shows a satellite prototype as viewed from an early SBD User interface prototype. Since a key feature of the user interface is its use of standard web browsers, it can easily use standard plug-in tools such as VRML viewers to display a wide spectrum of standard data types.

This particular user interface prototype lacks the elements for controlling analysis and design tools, but it does show how engineers can easily access information about the design elements. In this example, the window on the right shows a component hierarchy of the satellite and allows the user to access components like bus structure, power, propulsion, attitude determination and control system, thermal, and payload modules. Each of these components has its own decomposition, and the subcomponents are interconnected in various ways. Connections are maintained as part of the product definition.

The window on the left displays the satellite as viewed within a 3D visualization and interaction environment. This satellite prototype responds to a set of commands that can be used to deploy its solar panels and actuate mechanical devices on the satellite. Operating the satellite within this kind

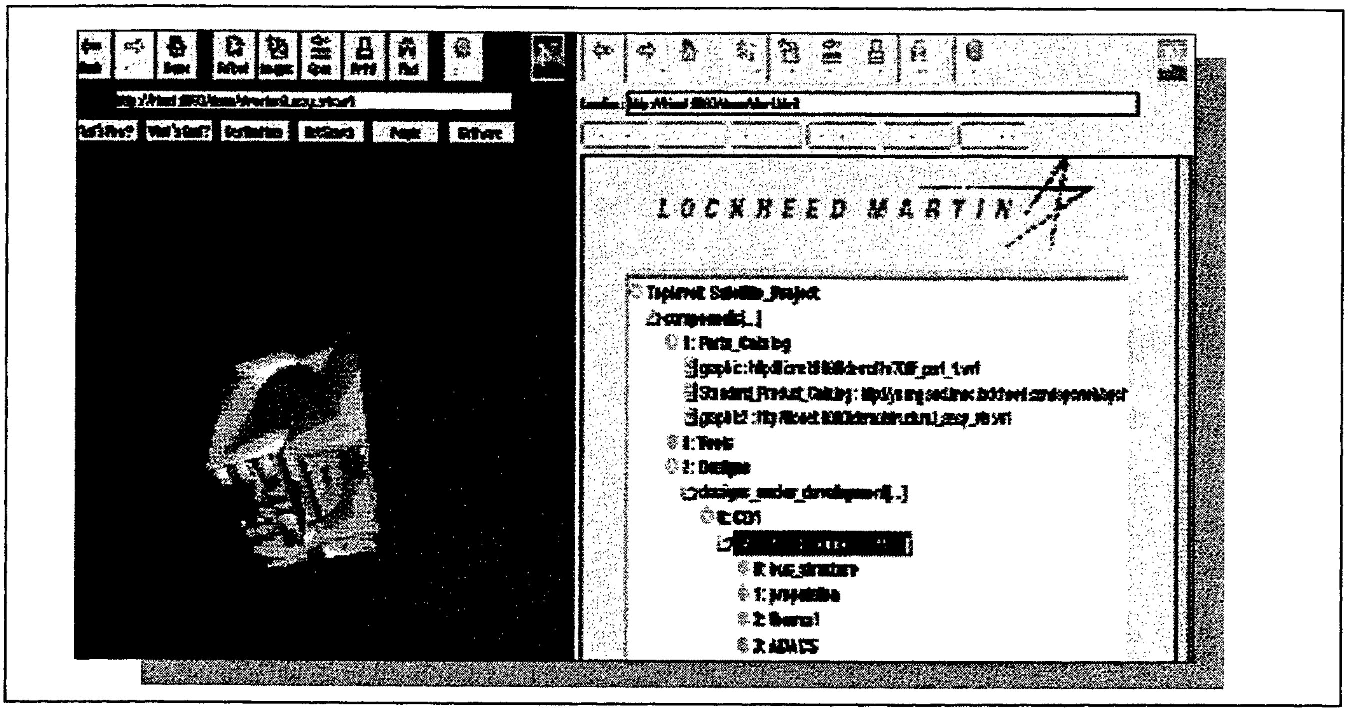


Figure 3. **Satellite Prototype Viewed from the SBD Guided User Interface (GUI)**

of environment can be used to evaluate a number of design properties such as sensor field of view, inter-satellite communications, ground station communications, mechanical interference properties of deployment and actuation devices, and advanced technology insertion. In this example, engineers used VRML to produce the visual appearance of the satellite, with the VRML being computed from the virtual product representation.

The specifics upon which modelers define virtual prototypes differ, depending on the level of fidelity needed and the data requirements of the tools used to evaluate the prototype. Easy to modify and clone, engineers can later reuse virtual prototypes as parts of other prototypes. New attributes (e.g., center of gravity) can also be added to a prototype when needed for a particular application.

Further, engineers can quickly generate an initial conceptual design to validate feasibility and provide a basis for cost estimation by reusing data from previous systems and by importing data from external tools. The virtual products can then be analyzed with existing or legacy analysis tools, and can be operated in virtual environments combining real and simulated products.

With SBD, engineers can also capture design processes, such as the steps in designing a power subsystem for the satellite, as mega-programs – or programs of programs – that are manipulated and operated exactly like the virtual prototypes.

Development proceeds within SBD by establishing product constraints and requirements and by constructing increasingly detailed virtual prototypes of the product. The virtual prototypes (software models) can be viewed, interacted with, analyzed, and operated like real prototypes. As engineers make design changes, analysis and evaluation of the prototypes takes place within synthetic physics-based environments. SBD not only manages these design artifacts, with built-in configuration management tools, but also allows engineers to incorporate components of different levels of fidelity within a virtual prototype.

Collaborating With SBD

Complex product development typically involves multiple heterogeneous organizations. The inter-connectivity needed for product development requires support for defining, managing, and enforcing development processes and the resulting workflow. In a large-scale product development enterprise, each team has its own data, product, and process models.

Since engineers configure a collaborative SBD system as a collection of copies of the common software, it works to provide seamless access to all public resources in the entire SBD system. Each user interface provides access to the rest of the SBD system, as mediated by the Core Processing System components.

SBD allows users to maintain their product data in one or more databases – legacy or new, flat file, relational, or object oriented – which can be either centralized or distributed. Each Core Processing System maintains an object model that is accessed from its user interface, for visualization and interaction.

A Project's View of SBD

SBD uses object models to represent all product and process information. Within an enterprise's organizational hierarchy, object models, collectively called the Smart Product Model

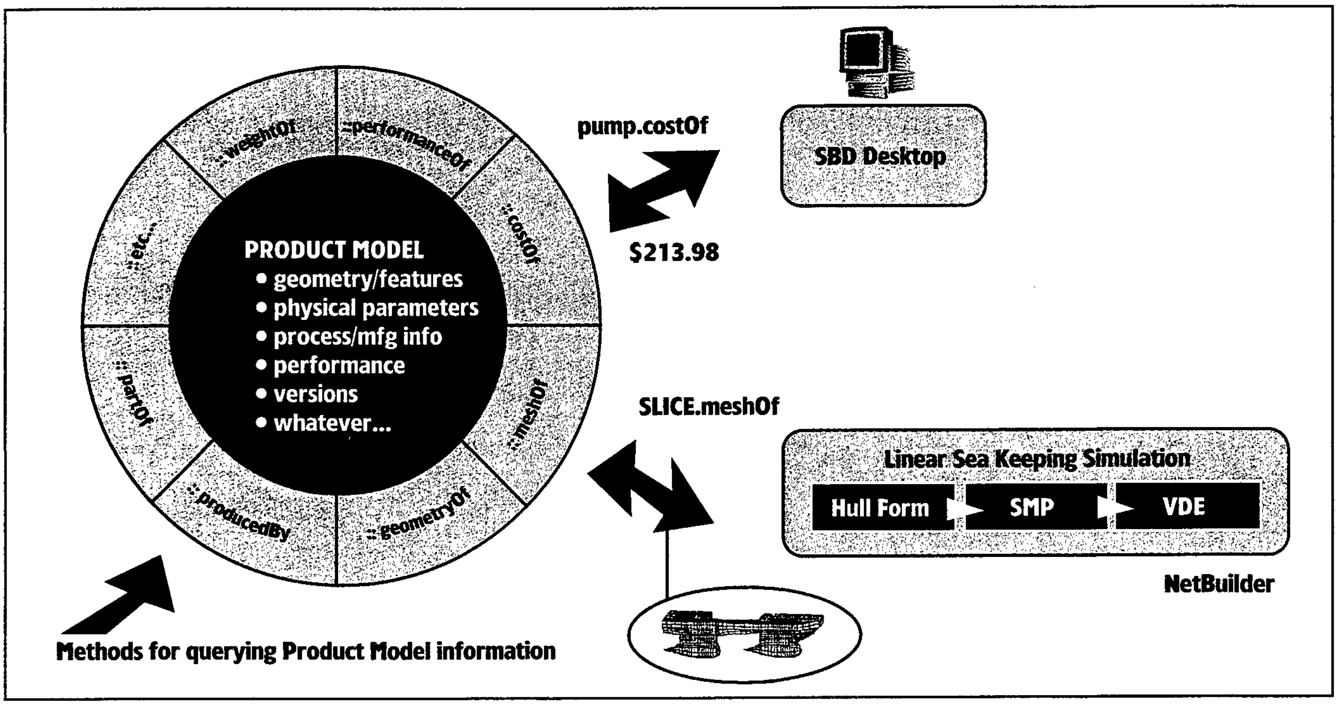


Figure 4. **A Logical View of the SPM**

(SPM), define and manage the development process, the external software and databases that are part of a specific SBD configuration, as well as the product models that engineers develop as part of the life-cycle process.

The SPM may be viewed as a collection of concentric circles with data at the center; "smart" methods that directly operate on the data in the innermost ring; software components that provide value-added services such as 3D viewing and interaction with product model data as the next ring; and finally, external programs that interface to the core data as the outer ring.

Figure 4 illustrates this view of the architecture for a notional ship design project.

This architecture is a natural extension of the single CAD model approach used on large programs such as Boeing 777. Integrating behavior, management, and analysis data into a single virtual enterprise-wide distributed data model ensures that all members of the team always have access to all information relevant to their design, and that the impact of design or management changes – such as schedules or budgets – can be immediately assessed by all team members.

The object models are "smart" because they have methods that are used to perform analysis and other development activities. Methods are the means to manipulate or analyze data such as meshing of CAD data for structural analysis, aerodynamics for aircraft maneuverability, or a seakeeping model for ship motions. As such, they can be aggregated to form views into the object model that are specific to a given discipline or user group. As an example, methods may be used to calculate the weight of an object as the sum of the weights of its components; or methods can be used to expose a data view relevant to the structural design engineer.

Conclusion

SBD is the first step toward fielding integrated acquisition-logistics synthetic environments. By harnessing advancements in M&S, High Performance Computing and Communications, and Multimedia technologies, SBD provides a virtual collaborative environment for geographically distributed IPTs to design complex systems and provide support throughout the product's life cycle.

Today, M&S is becoming increasingly important in acquiring systems for the government, but the potential cost reductions offered by correctly using M&S in the design process still dwarf deployed reality. Why hasn't the DoD acquisition community yet realized these substantial cost reductions? The answer is contained in the following three problem areas: tools don't interoperate, people are in the loop even when no decision-making requirements exist, and no standards for digital product and process models exist. SBD offers a solution to these problems by leveraging emerging standards and commercial forces for interoperability, by fielding a collaborative software environment infrastructure, and by creating de facto standards for product and process models.

The SBD program is unique in developing a virtual prototyping architecture for configuring reusable and interconnective SBD systems with standards-based interfaces. The ability to reuse and interoperate virtual products across multiple organizations and vendors is where SBD will pay off on a national scale.

Why is Modeling and Simulation So Hard to Do?

M&S Commonalities, Interoperable Systems Will Provide Warfighters, Decision Makers Increased Readiness Across Full Spectrum of Conflict

RONALD W. TARR

"No one knows exactly what warfare in the 21st Century will be like. However, one thing is certain – future battlefields will be far different and more complex than 20th Century battlefields. We must be ready...Finding ways to exploit our competitive advantages – quality people and advancing technology – becomes our future readiness challenge."

–Gen. Dennis J. Reimer
Army Chief of Staff

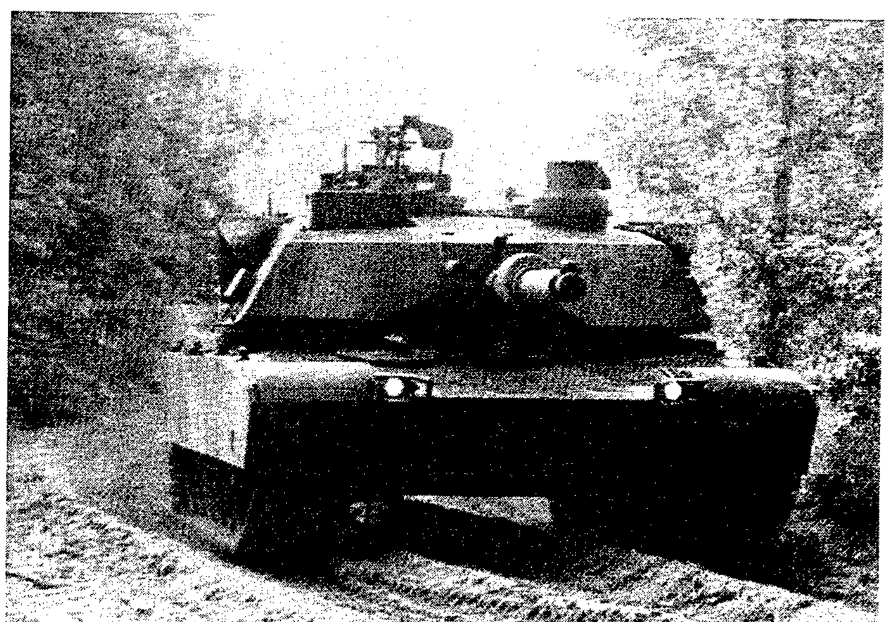
The issue of Simulation Based Acquisition poses an interesting dichotomy for the Defense Department and its support industries. On the one hand, it holds the potential to be the greatest tool to improve the acquisition process; but on the other hand, the number of systems and programs using simulation in new, innovative ways are few and far between. Given the enormous pressure to reduce costs, save time, and make innovative uses of technology in all facets of our lives, why does this obvious area of need seem to be lagging behind? It appears that the difficulties are not technological as much as they are cultural, organizational, and yes, even a function of policy.

The Stated Need

The use of modeling and simulation (M&S) in the military and its supporting industries is increasing. As these needs increase, the demand for non-technical personnel to provide management and leadership also increases. The senior leadership of each Service express these needs in their individual M&S plans.

The Army Model and Simulation Master Plan[1] promotes the adoption of M&S standards, common tools, and processes for use in all applications throughout the Army. In an effort to invest its resources in an effective and efficient fashion, the Department of the Army intends to use M&S technologies to significantly advance the capabilities of a smaller, power-projection Army capable of land force dominance.[2] The Master Plan requires that the Army seek opportunities for commonality within M&S technologies and capitalize upon them, wherever feasible.

The U.S. Air Force (USAF) Modeling and Simulation Master Plan states the Air Force goal for M&S is to develop a capability, using interoperable M&S systems, to provide warfighters and decision makers the tools to ensure readiness across the full spectrum of conflict.[3] Fully capable of supporting analysis and training, which is integrated throughout all echelons of the Air Force, the Air Force M&S architecture links together many



Tarr is a member of the Research Faculty at University of Central Florida, located in Orlando. He leads a team of inter-disciplinary researchers who function as planners, technology integrators, and educators of the modeling and simulation community. Tarr is a retired military officer and holds advanced degrees from Florida State University.

DoD photos unless otherwise noted

types of simulations (e.g., aggregate and detailed computer models, pilots in live aircraft and simulators, and hardware components).

The Air Force has always used models and simulations of reality, considering live field exercises as simulated warfare.[4]

The U.S. Marine Corps (USMC) desires to acquire and apply M&S technologies effectively and efficiently to support USMC roles and missions.[5] Recognizing that the use of M&S enhances training, education, analysis, logistics, planning, and the conduct of operations, the USMC also promotes the use of M&S as the very basis for improving future acquisition decisions, systems testing and evaluation, realignment of force structure, and requirements definition.[6]

The Marine Corps Modeling and Simulation Master Plan states that the Marine Corps will maximize warfighting capability by exploiting world class M&S technology in order to take full advantage of the explosion in information and communications technologies, thereby improving Total Force performance. By ensuring that it simulates before it builds, buys, or fights, the Corps will enhance readiness and training while simultaneously reducing costs.[7]

The Department of the Navy (DON) has stated it will use the appropriate level of M&S in order to support all phases and milestone decisions of the system acquisition cycle.[8] The end-state objectives of the Navy's M&S plan includes a full-scale integration of live, virtual, and constructive simulation into training endeavors, and the enabling of mission planning and rehearsal through the use of M&S.[9]

community. For years, senior acquisition leaders throughout the Department of Defense (DoD) discussed a future goal of streamlining the acquisition process. For people outside the military [and oftentimes, inside], the acquisition life cycle is almost unbelievable. For example, the Air Force began work on the F-14 as early as 1961, the M1 Tank in 1969, and the Stealth Fighter in 1978; in fact, an average acquisition life cycle of 15 years for even small systems is not unusual. The need to streamline is great, and the process has many points that would seem to warrant some technological improvements. Let's look at a few.

Concept Formulation/Defining Requirements. We're all familiar with the cartoon that shows the series of events illustrating how the camel evolved via

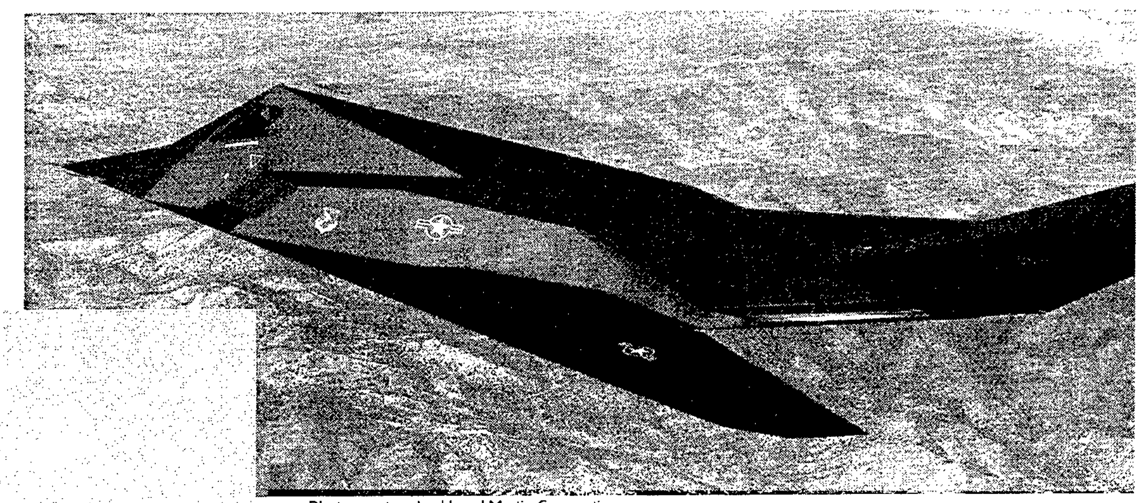
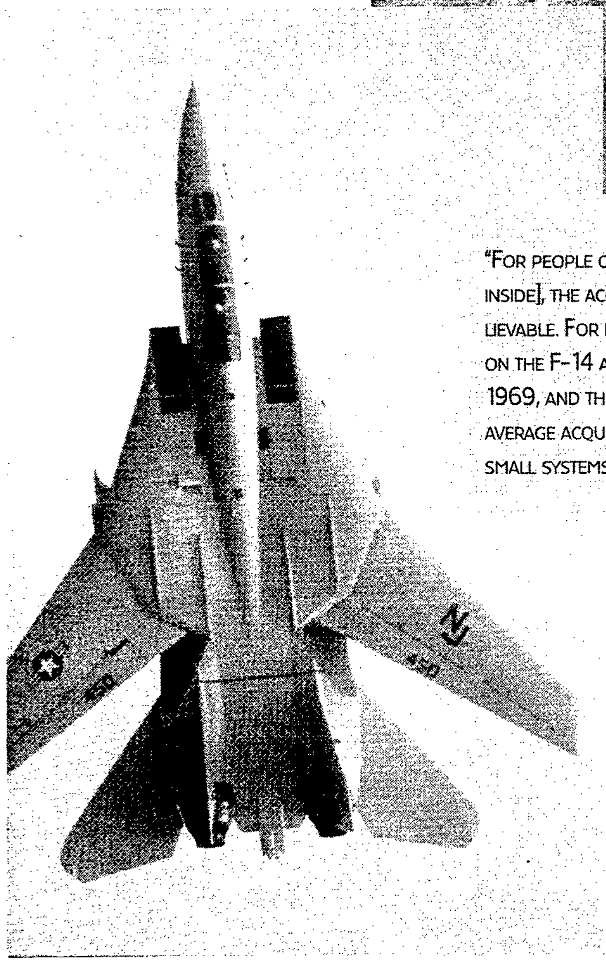


Photo courtesy Lockheed Martin Corporation



"FOR PEOPLE OUTSIDE THE MILITARY [AND OFTENTIMES, INSIDE], THE ACQUISITION LIFE CYCLE IS ALMOST UNBELIEVABLE. FOR EXAMPLE, THE AIR FORCE BEGAN WORK ON THE F-14 AS EARLY AS 1961, THE M1 TANK IN 1969, AND THE STEALTH FIGHTER IN 1978; IN FACT, AN AVERAGE ACQUISITION LIFE CYCLE OF 15 YEARS FOR EVEN SMALL SYSTEMS IS NOT UNUSUAL."

The Solution

The intent of all the Services and, in many cases, the Congress, seems quite clear, and many of us believe that the domain of M&S that could gain the most from this new technology is the acquisition

the acquisition process, when a horse was the original concept. Although a trite example, it does typify what we all experienced, as the user first describes the need and then passes it to the developer, who must then convert the idea into the best technical solution. The challenge is for the user to initially communicate the needed system in operational terms, while the developer must design and develop something that meets the needs in terms of a real, efficient, and maintainable item of equipment.

Further, this is often complicated by language problems, personnel turnover, technology changes, priority

changes, and leadership directions. Of course, the real problem is that users really have a difficult task describing what the new requirement is; by nature, they want everything, they want it today, and they want it cheap! Who can blame them when they are representing the needs of the warfighters, who are always faced with new missions and bigger challenges. The problem is that this often ambitious, yet less-than-detailed Operational Requirements Document (ORD) is very difficult for developers to implement. In addition, as modelers develop many of the capabilities, technical solutions often end up as useful but not consistent with the original requirement. This is not always recognized, as the documentation of the original need is not usually available to the developers. A very long trail, indeed....

Documentation. When the acquisition of the training subsystem alone includes a trailer truckload of documents, it becomes easy to understand why the documentation of the acquisition life cycle is so difficult to manage and often lags behind when development work becomes overwhelming. Certainly, modern information technology can alleviate this problem, simply by automating the existing complex "paper" process. Making use of the current techniques of distributed data systems, electronic conferencing, and Web-based document collaboration would provide not only a ready access to the ORD, but also provide an online ability to document decisions and actions throughout the process. The idea that one phase of the process could pass its experience on to the next, including issues that need resolution and key decisions that help accomplish the requirement, would reduce the time and transfer loss that happens at each milestone. The use of consistent state-of-the-art information technology alone would reduce the process by 15-20 percent.

Simulation in Defining Concepts and Development of the ORD. Remember the hardest thing about doing a term paper in high school? Most of us would probably reply that it was determining the topic and theme of the paper. This process is similar to trying to describe the functional capabilities of a new weapons system, which has become especially difficult with the transition from a requirements-based system to a capability-based approach. One promising alternative approach that uses simulation is the development of a notional system using a dynamic computer model, at the component level of the systems. Modelers would begin by first loading the system that currently exists into a computer simulation that can dynamically and graphically display the appearance and performance capability of the components that make up the system. Depending on the complexity of the system, it could end up being a multi-level model, consisting of "system of systems." As most systems are actually only about 25 percent new technology, the combat developer systematically works through each major sub-system, replacing components with either existing components from other military or civilian systems, or defining a new system based on functional capability. Plugging the new items in, of course, must include a reconfiguration of support systems and recalibration of performance parameters.

Once the developer completes the functional virtual prototype, initial operational testing comes next to determine the prototype's performance capabilities. By injecting the Virtual Prototype into a battle scenario, previously baselined with the existing system, modelers can then see if they are achieving the desired outcomes. Data can be collected for those components that are real, and can be approximated for the completely new pieces. Once the concept is tried out, the performance parameters and the documented functionality can be translated into an ORD, and the virtual prototype can be passed on to the developer to ensure proper understanding of the requirements and maintenance of all the information generated up to this point. Of course, key to this process is ensuring that modelers use the new concepts in such a way that performance can be accurately measured and evaluated in terms of system and sub-system performance, as well as operational and tactical ability. This takes us to our next streamlining opportunity.

Test and Evaluation. Easily the most underutilized element of the overall acquisition community, test and evaluation could provide 25- to 40-percent savings if properly employed throughout the life cycle process. In the first place, most programs wait until the end to begin involving the test and evaluation (T&E) community when, in fact, the T&E experts should be on board from the very beginning. First, at the onset of the concept formulation process, the T&E experts – who understand data collection, performance assessment, and measures of effectiveness – can assist in the formulation process by pointing out those processes already tried, and those that cannot be accurately measured, as described. As the concept is converted into a prototype (hopefully, a virtual prototype as described previously), the T&E experts can help set up ways to measure the effectiveness of the prototype, as well as set up and measure the test program against the current baseline system. In some instances, they can provide facilities or, at the very least, insight, into how to conduct virtual tests, and can even do sophisticated hardware-in-the-loop, engineering-level developmental testing. At the same time, they can develop the test process so that data collected can be used for two other key elements related to Operational Testing – Verification, Validation, and Accreditation; and cost effectiveness. They should also be able to assist in leveraging data from previous developmental tests on notional components from other test activities, further reducing the need for testing. When this is coupled with information technology automation techniques, and information on test experience begins flowing between agencies using and reusing compo-

nent-level data and evaluation tools, the process becomes more efficient, and the life cycle becomes shorter.

A lack of valid data to use in the models, and the lack of facility most of us continue to have in truly working with data-intense decisions, constitute two of the most basic reasons simulation is not easier to implement. Pound for pound, the T&E community has lived in this world much longer than the rest of us, and we could benefit greatly from their experience.

Other Issues. Certainly, I could go on and talk about other areas that could benefit from M&S technology interventions. These could include the use of simulations for setting up virtual production lines; determining parts needs and stock levels; using simulation to simultaneously develop the necessary training systems; using the same notional approach described previously, with its resultant data trail to forecast RAM and logistics support and using a mix of the predecessor data and information available for the components connected together. This discussion could go on for quite some time. However, the examples I just cited should be enough to make the point that the use of simulation in acquisition is not a mysterious process, but rather the managed systematic integration of a new set of technology tools, in an innovative fashion. But, a few stumbling blocks, which are not technical but rather cultural and organizational, may impede the way.

M&S is used everywhere in the Air Force because better decisions and better training make better warfighters.

—1995 U.S. Air Force Modeling and Simulation Master Plan

The Problem

Presently, no focused, organizational method exists that ensures individuals are versed in the issues and methods surrounding M&S applications except by on-the-job training. Even within academia, only a few graduate degree programs in Simulation Systems are offered.[10,11] Despite this apparent lack of formal training and education, the need for DoD's expanded use of M&S continues to be viewed as a major solution, for the acquisition world and its activities continue to grow at a significant rate. Without a formal strategy for developing M&S professionals, neither consistent application nor functional standardization within the M&S community can be achieved, and acquisition will continue to go on as usual.

In addition, until the Federal Acquisition Regulation changes, many of the steps and streamlining options are, in fact, not allowed. Unless program managers receive sufficient latitude to employ these alternative techniques without the expectation that they must solely endure the pain and shoulder the risks, on those occasions when the fledgling technology fails, they will not take the risk. Only when the Departments sponsor key programs to do some classic side-by-side comparisons of applications using simulation versus traditional approaches, can the new technologies prove they will work, saving time and money. Then it will be possible to see Simulation Based Acquisition achieve its essential role.

Let me briefly take you back in history a few years. At the risk of sounding trite, our civilization is just beginning to shift from the Industrial Age to the Information Age; we are going through all the dynamic and sometimes painful processes of change. If we look at how long it took our culture to go through the Industrial Revolution, we can imagine what's in store for us. Shifting from a focus on products and assembly-line thinking to information services and distributed collaboration, will clearly be a large leap. Planners, modelers, program managers, product managers – for many in our acquisition workforce, this shift in focus may not seem efficient or pleasant.

When we add these issues to the challenges resulting from the end of the Cold War and the huge push to expand to "operations-other-than-war" missions, our culture is going through an era that makes the '60s look positively calm. Only by systematic planning and careful application of new technologies, with an eye always toward the best outcome, can this process be streamlined and acquisition become one of the domains that makes full use of available technology.

Endnotes

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2. *Ibid.*
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4. *Ibid.*
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Air Force Modeling and Simulation Trends

Modeling and Simulation Makes Possible the Unaffordable

WILLIAM K. MCQUAY

Modeling and Simulation (M&S) is already an integral part of the way the Air Force conducts business. Current use of M&S by Department of Defense (DoD) program and product managers extends throughout the Air Force; from research, development, acquisition, and sustainment, to training and operations (Figure 1).

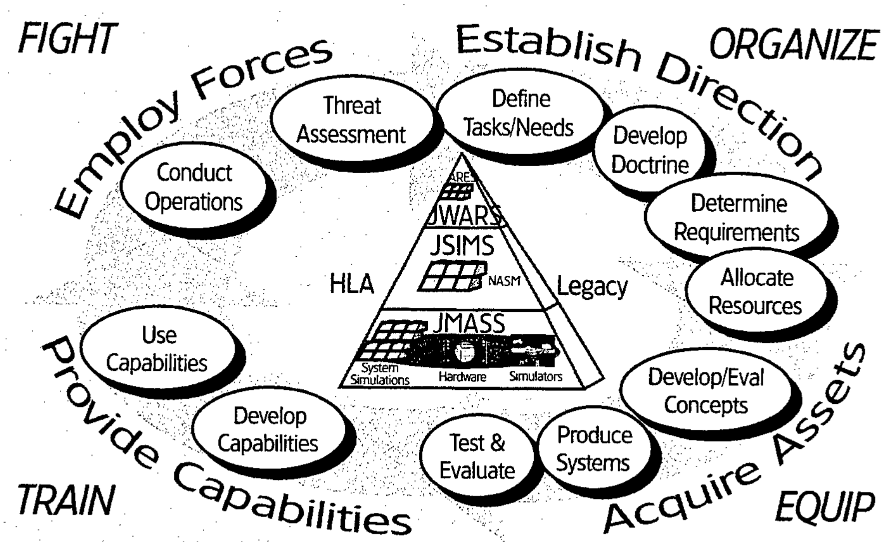

Figure 1. **M&S in the Air Force Enterprise**

The New M&S Vision

The Air Force envisions an integrated, common M&S environment that will be accessed by analysts, warfighters, developers, and testers supporting the range of Air Force tasks, from determining requirements through conducting operations. This article summarizes trends in the new vision for M&S and in the simulation technology that can be employed to implement simulation systems of the future. Joint M&S standards will provide key advanced technologies for future simulation applications.

Throughout the rest of the decade, the use of M&S will increase throughout all functional areas in the DoD. Because of increased technical capability and increased fiscal constraint, including DoD-mandated budget reductions in other areas, M&S utilization will continue to expand. Further, M&S allows DoD organizations to do things that would otherwise be unaffordable (i.e., thousands of parametric sensitivity tests on new systems) or physically difficult-to-accomplish military worth studies on proposed force structures against threat command and control systems).

Recognizing the importance of M&S, the Department issued a DoD Directive on "DoD Modeling and Simulation Management," that provides for a DoD M&S Master Plan. As part of the Master Plan, DoD established a common, High Level Simulation Architecture to assure not only the appropriate interoperability of simulations, but their interface with command, control, communications, computers, and intelligence (C^4I) systems. The goals of the High Level Architecture (HLA) include several areas:

- Interoperability
- Reuse
- Portability
- Distributed Operation
- Legacy Operation
- Scalability
- Broad Applicability
- Technological Evolvability
- Commercial Off-the-Shelf (COTS) Products
- Government Off-the-Shelf (GOTS) Products

DoD adopted the last two goals as part of its acquisition reform strategy to

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make maximum feasible use of off-the-shelf products.

Today's simulations are narrowly focused, stovepiped developments for each user community. Specifically, they do not fully meet Joint needs; take too long to build; cost too much to build and operate; lack verification, validation, and accreditation; are not interoperable with each other's M&S assets; and are not easily maintainable or extensible. High-level DoD and Air Force senior acquisition managers share a consensus view on the need to interoperate and reuse models, simulations, and related products across Service lines; across traditional communities (e.g., linking models and simulations to C^4I systems); across functions (e.g., sharing capabilities between operations and acquisition); and across classes of models and simulations (e.g., linking live, virtual, and constructive simulations).

Today's simulations are narrowly focused, stovepiped developments for each user community. Specifically, they do not fully meet Joint needs; take too long to build; cost too much to build and operate; lack verification, validation, and accreditation; are not interoperable with each other's M&S assets; and are not easily maintainable or extensible.

The effective use of models and simulations across DoD requires a common technical framework for M&S to ensure interoperability and reuse. Embodied in this technical framework will be a common HLA to which models and simulations must conform; conceptual models of the mission space to provide a basis for the development of consistent and authoritative simulation representations; and data standards to provide common representations of data across models, simulations, and C^4I systems.

Air Force program and product managers are in general agreement that no single model or simulation system can satisfy all uses and users. Further definition and detailed implementation of the specific simulation system architectures, which will be HLA-compliant, will remain the responsibility of the developing Service or Agency. The HLA will specify only the minimum definition required to facilitate interoperability and reuse. The DoD HLA is central to the M&S Master Plan.

One way to view this simulation HLA is to think of a city planner or architect. A building is compliant as long as

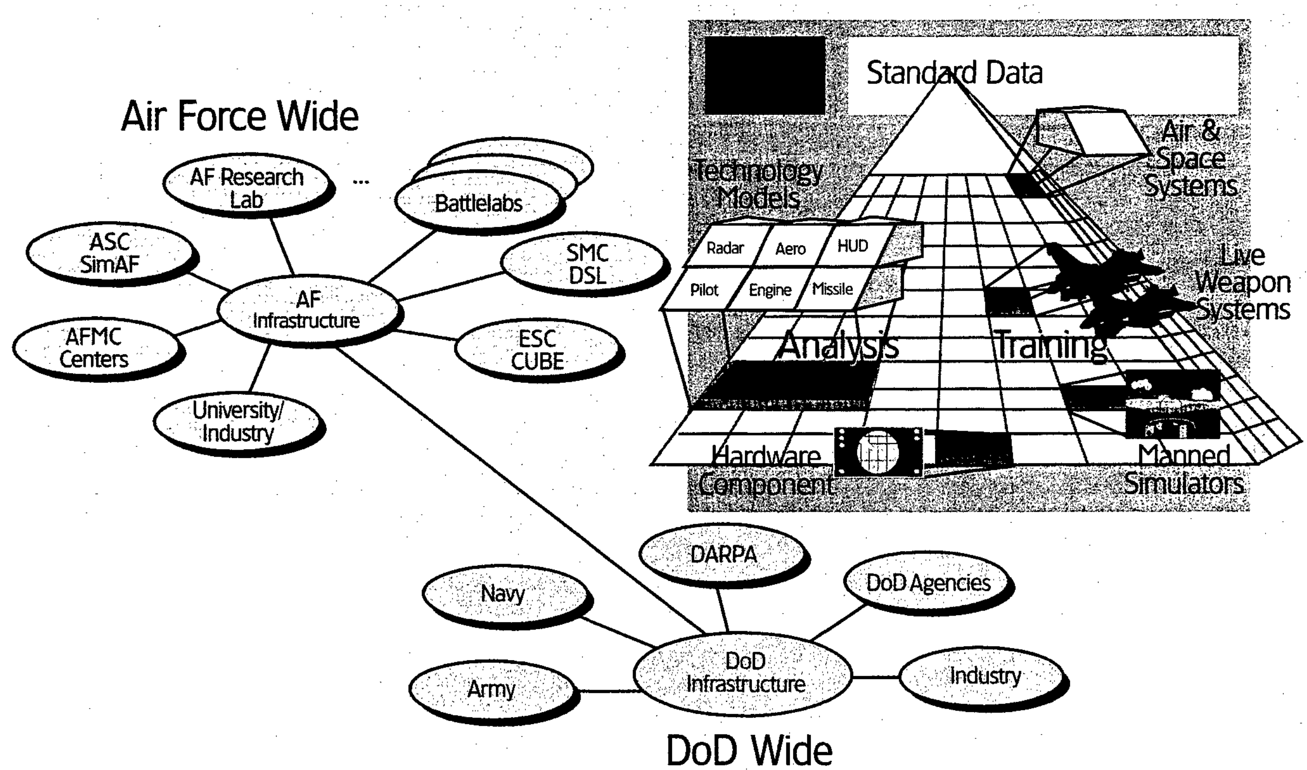

Figure 2. **Joint Synthetic Battlespace**

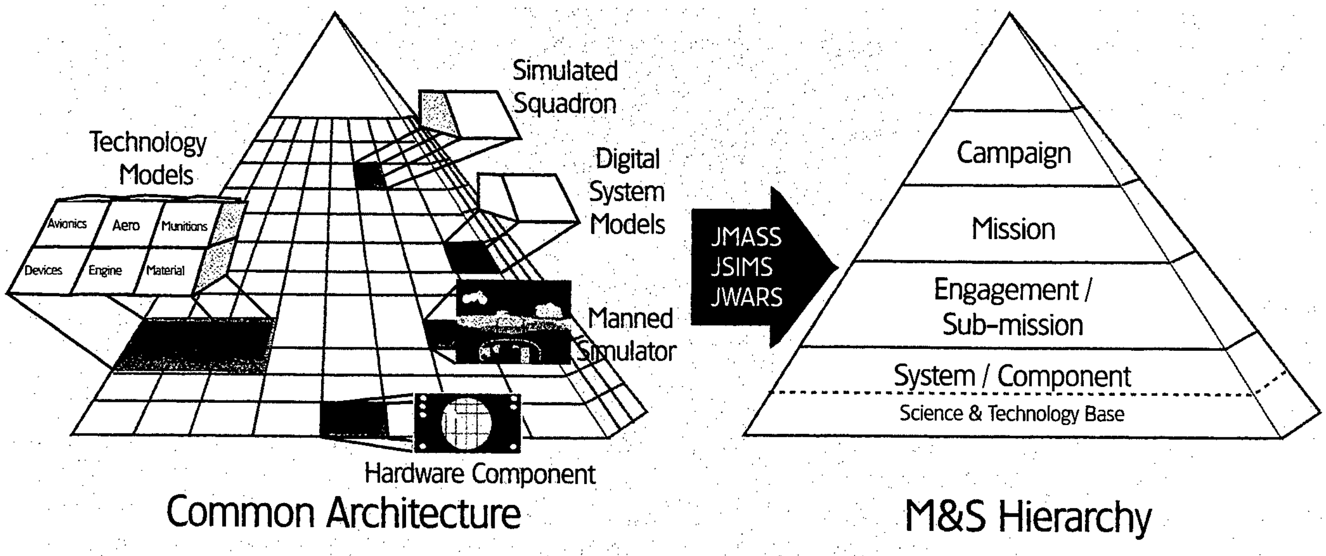

Figure 3. **The Air Force M&S Architecture**

you get the right permits and follow the building codes and standards. Similarly, new models would be required to follow specific standards to fit within a certain general architecture. The DoD M&S Master Plan and subsequent DoD directives require a review and oversight of all ongoing DoD M&S projects and programs for compliance with the HLA and phase-out of non-compliant programs by FY 01.

A New Vector for Air Force M&S

Consistent with the DoD vision, the Air Force envisions an integrated, common M&S environment accessed by analysts, warfighters, developers, and testers; and supporting the range of Air Force tasks, from determining requirements through conducting operations. On June 9, 1995, the Air Force convened an Air Force Four Star M&S Summit to create an M&S roadmap. The resultant roadmap defines a future vision for Air Force simulation and describes near-term and mid-term goals. Achievement of those goals is expected to move the Air Force closer to M&S commonality; and also a consistent representation of aerospace forces for Joint use.

The key concept in the Air Force M&S vision is the Joint Synthetic Battlespace – an integrated M&S environment, connecting analysis and training and tying together many types of simulation (Figure 2). The simulations extend from high-level aggregate models to detailed engineering models; from pilots in live aircraft and simulators, to hardware components and laboratory test beds.

The Air Force M&S infrastructure focuses on three key initiatives:

- **Joint M&S Integration Program** (JMSIP) – a coordinated approach to improving air and space representation in our legacy models and simulations while consolidating into fewer models that meet the requirements of many.
- **Joint Standards** – a commitment to Joint M&S developments with supporting Air Force initiatives.
- **Advanced Distributed Simulation Leveraging** – programs to provide high-speed connectivity between Air Force installations, multiple networked air combat training simulators for each wing in the Air Force, and a synthetic battlespace for Joint Force Air Component Commanders.

In the near-term, JMSIP will focus on the need to corporately address M&S improvements and the need to encourage consolidation. Addressing these two vital needs will serve as a leveraging effort, producing an Air Force M&S Roadmap that maximizes common efforts and targets improvements based on a corporate assessment of their importance and urgency.

For the mid-term and in accordance with overall DoD direction, the Air Force will implement simulation standards through defined architectures and simulation systems that support them. Each product center has or is developing a portal into the Joint Synthetic Battlespace of the future for *system of systems* evaluations and a key part of the current Air Force M&S infrastructure – Aeronautical Systems Simulation Analysis Facility (SimAF), Electronic Systems Command and Control Unified Battle Environment, and Space and Missile Center's Decision Software Laboratory.

In addition to key facilities, M&S standards will generate greatly improved simulation interoperability, allowing the Air Force to leverage simulation investments. The Air Force has targeted three major simulation standards efforts in the roadmap for high-level Air Force oversight and investment. All will participate and adhere to the DoD High Level Simulation Architecture initiatives being directed by the Director, Defense Research and Engineering, and managed by the Defense Modeling and Simulation Office:

- The Joint Simulation System (JSIMS) is a distributed, object-oriented simulation architecture and system focused on the *operational level of war* (campaign and mission level simulation).
- The Joint Warfare Simulation (JWARS) focuses on Joint campaign analysis.
- The Joint Modeling and Simulation System (JMASS) is an Air Force-directed program to develop and deliver a distributed, object-oriented simulation architecture and system focused on the *tactical level of war* (mission and engagement simulations).

These Joint standards and the systems that support them will enable interoperability and reusability of Air Force M&S tools across key communities and processes. The Joint standards serve as GOTS frameworks for the addition of third-party applications. These initiatives, coupled with ongoing improvements and standards, will bring the Air Force measurably closer to the objective of a common, integrated M&S system (Figure 3).

Computer and Simulation Technology Trends

The changes reported in this article and resultant revision in the DoD and Air Force M&S visions, motivated by changes in computer and simulation technology, reflect current trends throughout the DoD. In the past decade, computer hardware technology improved several orders of magnitude: microprocessor speed alone increased about 100-fold. The overwhelming trend is faster, smaller, and cheaper. This reduction in cost and size, coupled with an increase in speed and capacity, resulted in a massive increase in simulation capability. Computational power continues to increase as prices decrease.

As the decade moves on, *a multiprocessor on the desktop* will be commonplace for simulation and analysis. It will be accompanied by the continued decentralization away from the central site to distributed computing personal processors close to the user, mixed with computationally intensive servers on a heterogeneous network.

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Object-oriented (OO) software technology is having a major impact on simulation technology as well as software in general. For software developers, OO software addresses three major problems: iterative development, reuse, and maintenance. Since up-front requirements definition is difficult, many successful OO projects employed an evolutionary, iterative process for development. Object-orientation can also promote reuse through a library of reusable objects. When combined with reuse and visual programming, OO technology can increase productivity, and therefore lower cost and decrease time for software development.

Software development has been historically labor-intensive. To date, even computer aided software engineering tools have not dramatically increased productivity. Producing the needed improvement will require a major paradigm shift.

OO technologies, combined with visual approaches and an engineering discipline to software development via a software structural model methodology, can finally bring the needed breakthrough. OO technology will allow implementation of component-based software as the construct for software reuse. By employing component-based design, users can be divided into four roles:

- **Appliers** – configure input data and execute existing simulations.
- **Assemblers** – establish connections among component parts found in a reuse library to build simple custom applications or models without professional programming assistance.
- **Power Assemblers** – go beyond piecing component parts together by implementing more complex logic.
- **Fabricators** – build new component parts

Advanced User Interfaces will extend the now common Graphical User Interface into an agent-based multisensor user interface that will incorporate features such as voice synthesis and voice recognition. Future computer software architectures will incorporate Manager-Agent and Remote Programming. In Manager-Agent programming, the client computer sends an object that the server executes. The object is called an agent because it acts on behalf of the sending computer. In Remote Programming, the client and server can interact independently of the network once the network transports the agent to the server. These intelligent agents act like assistants rather than tools: they will show more initiative, assume responsibility for larger subtasks, and take appropriate risks (rather than confirming every detail with the user).

As computer and software technologies advance, they change the face of modeling and simulation. Simulation technology has evolved from stand-alone models, to model hierarchies, to an integrated modeling system (Figure 4).

Future advanced modeling systems will include the following characteristics:

- Open systems architecture supporting applications conforming to commercial and industry standards.
- Visual paradigm — visual programming, visual assembly, visualization of output results.
- Object-based to allow component reuse.
- Extensible architecture for future software concepts.
- Web-based, browser-type user interface on the desktop.
- Execution on distributed heterogeneous network of workstations and upscale PCs.
- Tools to support development of model components.
- Multiple language support — the user can specify the target source language (C, C++, Objective C, Java, Ada83, Ada95, VHDL, etc.).
- Object-oriented database.
- Tools and models support a "Plug and Play" concept.
- Supports "distributed model development" by the domain experts as opposed to central model development by software experts.
- Provide a repository of models and their components.
- Documentation designed to support software reuse.
- Verification, Validation, and Accreditation (VV&A) integral to the software development.
- Compliant with the DoD High Level M&S Architecture.

> **The future vision for Air Force simulation is a flexible, integrated simulation environment that supports the full range of Air Force activities. Revolutionary and evolutionary advances in computer and software technology provide significant opportunities to implement this modeling and simulation vision.**

Summary

The future vision for Air Force simulation is a flexible, integrated simulation environment that supports the full range of Air Force activities. Revolutionary and evolutionary advances in computer and software technology provide significant opportunities to implement this modeling and simulation vision. The new M&S technologies will permit the creation of simulations tailored to the user's need, at a greatly reduced cost in time and money, and with elements of proven quality. Admittedly, achieving the simulation vision will require patience, perseverance, and significant investment to overcome many challenging problems, but the potential payoff is extremely high.

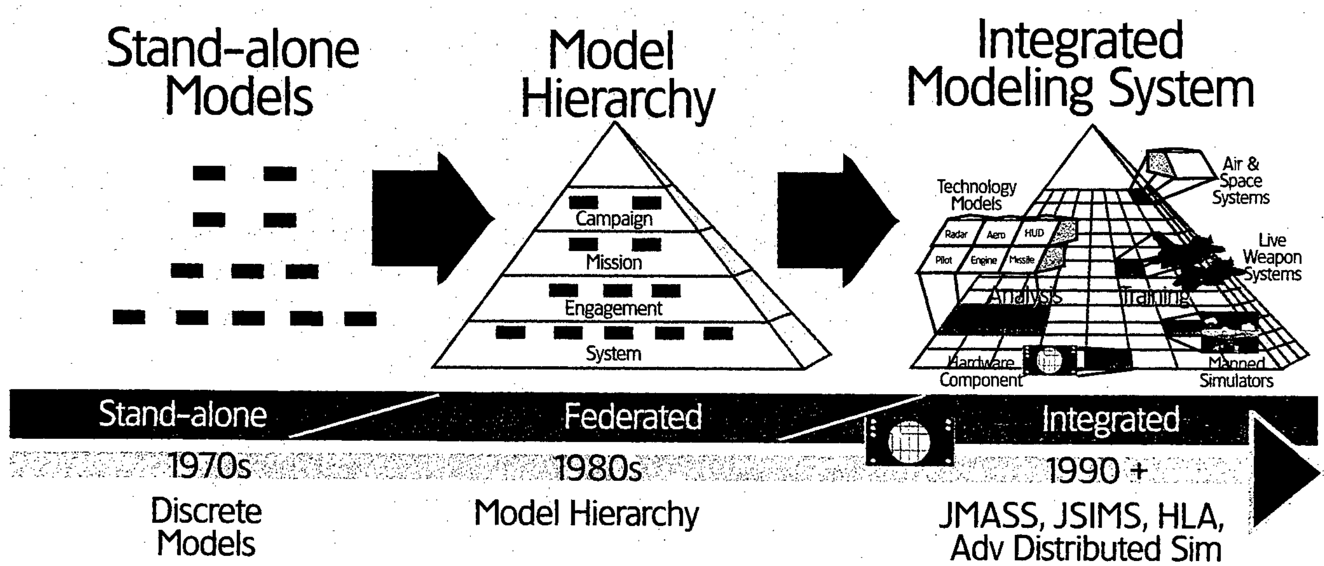

Figure 4. **Evolution of Simulation Technology**